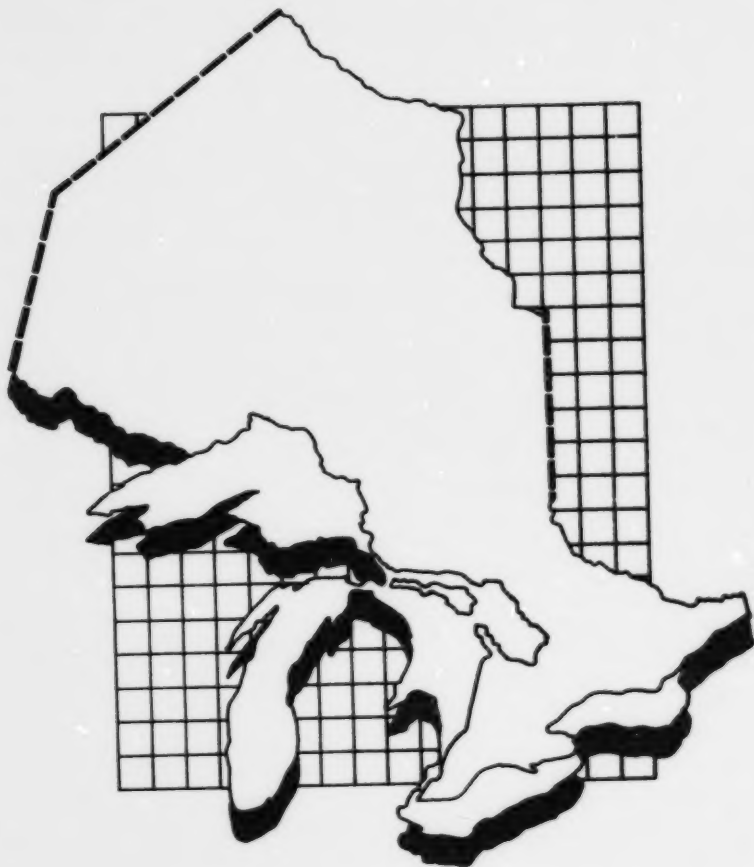


Estimating Energy Consumption for New Development



Ontario

Ministry
of
Energy

Honourable
Robert Welch, Q.C.
Minister

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ESTIMATING ENERGY CONSUMPTION

FOR

NEW DEVELOPMENT

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ABSTRACT

Estimating Energy Consumption for New Development is a manual designed to allow planners to estimate the total annual energy consumption associated with the construction and servicing of new development. Residential, industrial, commercial and institutional worksheets are provided. All calculations can be performed by using a hand calculator and through reference to the Catalogue of data provided. The annual transportation energy associated with each land use, the annualized energy consumption associated with site development, and the energy used in providing services is also attained through the use of single worksheets. The estimated annual energy consumption of the project, expressed in gigajoules, is the sum of the results of the relevant worksheets.

To facilitate the use of the worksheets, the manual contains a Catalogue of average industry-wide data and coefficients for space heating, transportation, construction of buildings and services and operation of municipal services. Case studies for three different developments demonstrate the application of the worksheets and illustrate how the manual is used. Conclusions are drawn from the case studies and recommendations made for energy-saving measures for more efficient land use planning.

EXECUTIVE SUMMARY

The objective of this report is to make available to planners a simple method for estimating the total energy consumption of new residential, commercial, industrial and institutional development.

The study was conducted for the Ontario Ministry of Energy by Marshall Macklin Monaghan Limited, with the assistance of the University of Toronto - York University Joint Program in Transportation. Study management was carried out for the Ministry by Currie Coopers and Lybrand Ltd.

The terms of reference for the study state that:

"It is often assumed that some forms of development are inherently more energy-efficient than others, e.g., compact medium-density development vs. sprawl or rural estate development. The travel, servicing and construction energy costs are different for each, yet little documentation exists as to the actual energy consumption associated with the various development patterns, and a simple means for estimating the energy use is not available. This study is intended to provide planners with a means of estimating the energy consumption of development projects."

The basis for the methodology employed throughout the manual is a worksheet which specifies all of the information which the user requires to perform the calculations. The worksheet is set up in a manner which guides the user through the calculations, all of which can be performed on a simple hand calculator.

The basic energy unit in the calculations is the mega-joule, i.e., one million joules. No attempt has been made to convert energy units to cost in dollars.

The manual can be used to compare total energy consumption of different forms of new development and different land use mixes on the same site. It can also assist in targeting important areas for conservation

measures. It can not be used as a definitive means of calculating energy use of individual buildings and should not be applied to existing developments, which do not have the energy characteristics of new buildings constructed under current building codes.

There are seven basic worksheets, one each for calculating total annual energy consumption of residential, commercial/institutional, and industrial buildings, one for annual transportation energy use (both public and private), one for annualized energy consumption related to construction of site services, one for the energy consumption of operating municipal services, and one for aggregating the energy consumption total for the project.

A major feature of the manual is the Data Catalogue. This provides the user with both data and detailed guidance in selecting the inputs for the worksheets. The Catalogue is divided into seven sections. With the exception of Section B, which provides a methodology to calculate detailed space heating requirements of a particular structure, each section of the Catalogue provides all the data and coefficients for one of the worksheets.

Three case studies of typical mixed use developments in Ontario are evaluated using the worksheets and data catalogue. Each case study includes a complete analysis of two alternative development concepts. The examples include a residential subdivision in a town, a secondary plan in a larger city and a suburban town centre development.

Finally, the study makes a number of recommendations for potential energy savings in new developments, the impacts of which can be analyzed using the methodology developed in this manual.

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Note: Each section of the Data Catalogue contains a separate Table of Contents.

BLANK WORKSHEETS

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Note: Lists of Figures precede each section in the Data Catalogue

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Note: Lists of Tables precede each section in the Data Catalogue

TABLE OF CONVERSIONS

1 joule (J)	=	9.485×10^{-4} BTU
	=	0.2390 calories
	=	2.778×10^{-7} kilowatt-hours (Kwh)
1 mega-joule (MJ)	=	1,000,000 joules
1 giga-joule (GJ)	=	1,000,000,000 joules
1 litre of gasoline typically yields		34.84 MJ of energy
1 litre of diesel fuel typically yields		38.66 MJ of energy
1 litre	=	0.2200 Imperial Gallons
1 kilometre (km)	=	0.6124 statute miles
1 square metre (m ²)	=	10.76 square feet
1 hectare	=	2.471 acres
	=	10,000 m ²

ABBREVIATIONS

BTU	-	British Thermal Unit
C	-	degree celsius (Centigrade)
DD	-	Degree Day
GJ	-	giga-joule - one billion joules
ha	-	hectare
J	-	joule
km	-	kilometre
kwh	-	kilowatt-hour
l	-	litre
m ²	-	square metres
MJ	-	mega-joule - one million joules
pass.	-	passenger
SIC	-	Standard Industrial Classification
Veh	-	Vehicle

1.0 INTRODUCTION

This manual is designed to assist municipal planners and individuals involved in the development of land to estimate the energy consumption for new development. The estimating procedures in this manual consider both the initial energy consumed by construction and the yearly operating energy consumption. The manual is organized to lead the user through a series of calculations presented in the form of worksheets. The user need only complete those worksheets that relate to the new development to be analyzed. There are six primary and a summary worksheet each with a detailed step-by-step explanation of how to use them.

The user is encouraged to provide local information to attain a result which will be more reflective of local conditions and thus more accurate. It is recommended that the first-time user read the manual thoroughly with emphasis on the sample calculations shown on the worksheets in Chapter 3. An understanding of these calculations will provide a basic knowledge of the methodology, the information required and where data is located in the Catalogue. A more complete awareness of the scope and applications of this manual can be obtained from a review of the Case Studies in Chapter 4.

The primary objective of this manual is to provide a simple methodology to calculate the annual energy consumption of new developments.



2.0 BASIS OF THE METHODOLOGY

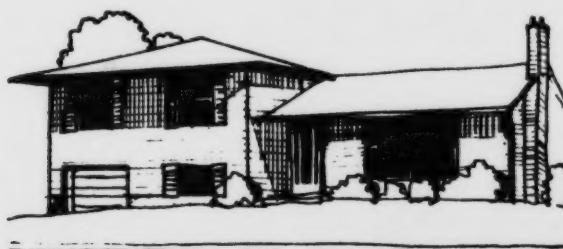
2.1 Introduction

In estimating the total annual energy consumption in a new development, the following components must be considered.

- i) the construction and operation of the buildings contained within the development site;
- ii) the use of private auto and public transit to travel to, from and within the development site; and
- iii) the construction, maintenance and operation of site services and infrastructure.

The basis for the methodology is a worksheet which specifies all the information which the user requires to perform the calculations and which also guides the user through these calculations.

Sketches of the standard residential unit types with average gross floor area noted are illustrated throughout this chapter.

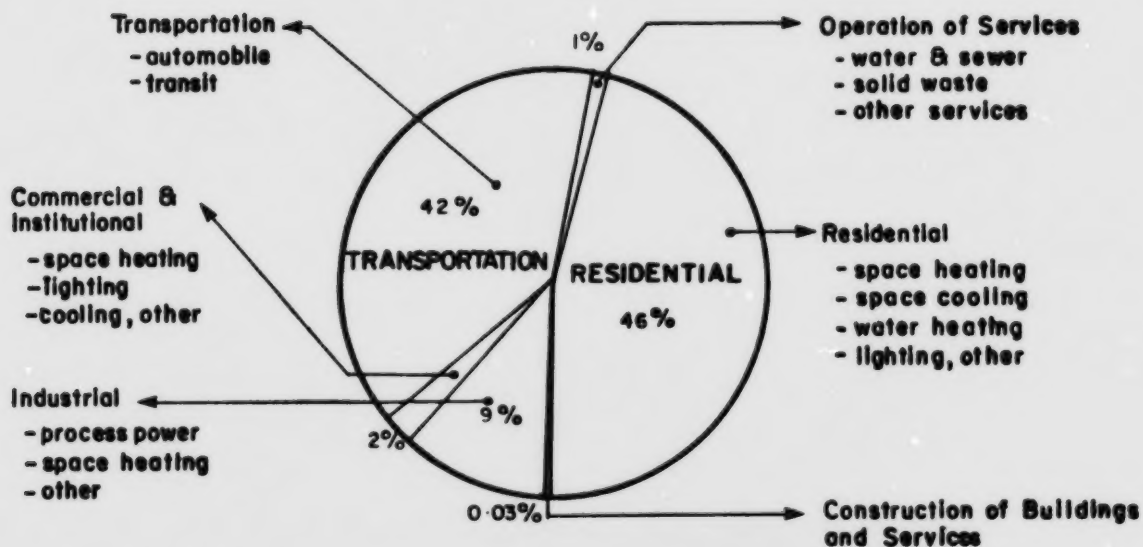


Split Level House (108 m²)

To provide an appreciation of how energy is generally consumed in a new development Figure 2.1 illustrates the distribution that can be expected in mixed use projects. The percentage figures shown are for purposes of comparison and will vary from development to development. This illustration demonstrates the predominant role some components have and should encourage the user to pay special attention to the input data and coefficients used in the worksheets.

FIGURE 2.1

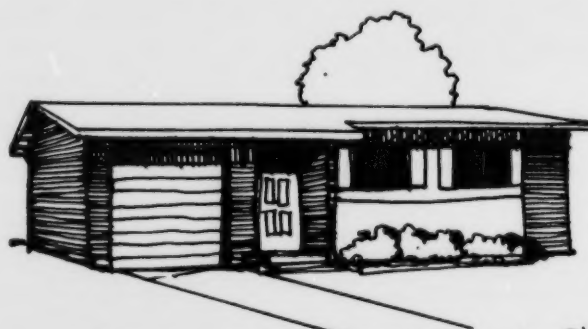
ENERGY CONSUMPTION IN A
RESIDENTIAL/INDUSTRIAL SECONDARY AREA



2.2 Common Unit of Energy Measurement

The basic unit of energy measurement used throughout this manual is the joule. The joule was chosen because the joule is the standard metric unit of energy and because it facilitates comparisons and calculations across energy sources (e.g., the

addition of x cubic metres of natural gas and y kilowatt-hours of electricity to yield the total energy consumption of a residential unit). Numbers are expressed in mega-joules (or, occasionally in giga-joules -- one thousand million joules) because the joule is a very small amount of energy (e.g., heating an average bungalow for one day requires about 346 million joules or to move a typical transit bus 1 km requires 20 million joules). A table of conversions and abbreviations is provided at the front of the manual.



Regular One Storey House (97m^2)

2.3

Range of Applicability

The worksheets presented in this manual are based upon elementary calculations and simplifying assumptions. They are to be used as a means of obtaining not only a gross estimate of energy consumption but also a better appreciation of how energy is consumed in a new development. At this level of analysis, the methodology provides useful and reasonably accurate answers.



Two Storey House (103m^2)

The following types of problems can be analyzed using this manual:

- comparison of the total energy consumption of different forms of new development;
- comparison of the total energy consumption of different land use mixes of new development on the same site;
- general examination of the effect of different insulation and conservation measures upon space heating needs and total energy use; and
- identification of major components of energy use in new developments to target important areas for conservation measures;

There are limitations in the application of this manual to address energy related problems. The input data used in this manual has been developed from average figures and thus does not reflect subtleties in design and local conditions such as topography and climate.

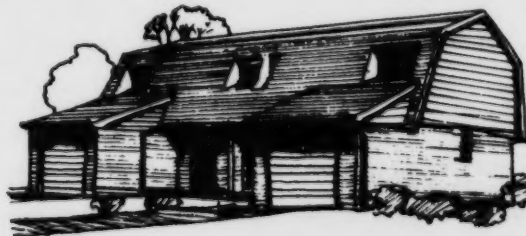
The worksheets should not be used to try to assess small scale design questions such as minor changes in residential unit designs or the impact of alternative street layouts on transportation energy consumption. Proper investigation of such micro-level issues involve the use of complex simulation models and a level of detail of design-specific data that is beyond the limits of the methodology presented within this manual.

In addition, this manual should not be used to estimate fuel savings, costs for operation of buildings, energy consumed by existing developments, the effects of solar orientation or the impact of a new development upon the total municipal or regional energy consumption.

2.4 Using the Manual

It is recommended that the user follow the steps listed below.

- Step 1 Read Chapter 3, "Energy Consumption Analysis" thoroughly.
- Step 2 Follow sample calculations provided on the Worksheets in Chapter 3 to see where data is obtained in the Catalogue and what information must be provided by the user.
- Step 3 Review the Case Studies presented in Chapter 4 to obtain an understanding of how the Worksheets are used together to calculate the energy consumption of a new development.
- Step 4 Collect data to be supplied by the user for the new development to be analyzed.
- Step 5 Obtain detailed local data that is available.
- Step 6 Obtain copies of blank Worksheets from the back of the manual.
- Step 7 Complete Worksheets with reference to project data, the Catalogue and detailed local data.



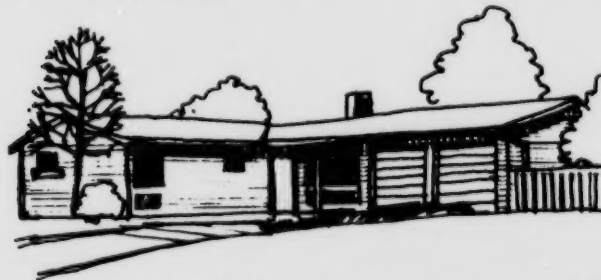
Semi-Detached House (103m²)

Note: For purposes of comparison and an understanding of the implications of introducing energy saving measures the input data can be modified and steps 8 through 10 followed for any number of sets of input data. It is recommended that at least three alternatives be prepared to provide a basis for evaluating the initial results.

Step 8 Review energy saving measures in Chapter 5, try to obtain additional local data and modify input data accordingly.

Step 9 Complete a second set of Worksheets with revised data.

Step 10 Compare first and second estimates and repeat Steps 8 and 9 as required to evaluate the impact of modifications to the input data.



L-Shaped One Storey House (164m²)

2.5

How to Use the Worksheets

The worksheets are specifically designed so that no specialized knowledge of energy consumption relationships, building construction techniques, transportation demand forecasting, etc. is required. The modular nature of the worksheets allows use of only those worksheets pertinent to the development being analyzed. Thus, if the site under analysis has no industrial development, then the user simply does not use the industrial worksheet. Similarly, if transportation energy consumption is not of interest within a particular planning context, then the transportation worksheet need not be used.

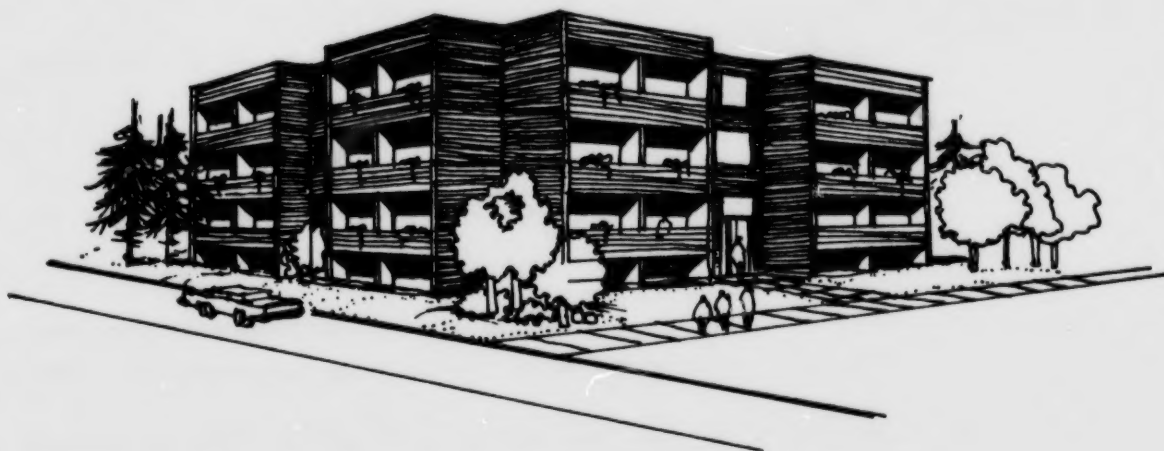
Two types of data are used in the worksheet calculations: site-specific data which must be supplied by the user and energy-related data (energy consumption rates, etc.) which are used to translate the user-supplied site characteristics into energy consumption estimates. The energy-related data is provided by this manual in a catalogue of data that is hereafter referred to as the 'Catalogue'. The source and "flow" of information within each worksheet is carefully labelled so that it is clear whether any given number used within a worksheet must be supplied by the user, is generated by a previous calculation within the worksheet, or is obtained from the Catalogue.

Seven worksheets are used in this manual, one for each of the following tasks:

1. calculation of the total annual energy use of all residential buildings within a site;
2. calculation of the total annual energy use of all commercial and institutional buildings within a site;
3. calculation of the total annual energy use of all industrial buildings within a site;
4. calculation of the total annual transportation energy use generated by private automobile and public transit trips to, from and within a site;
5. calculation of the annualized energy consumption associated with the construction of all buildings and services on a site;
6. calculation of the total annual energy required to operate water, sewage and solid waste services; and
7. calculation of the total annual energy consumption for the new development being analyzed. This is the sum of the totals generated by the other six worksheets. A summary of the energy indicators is also provided.

The calculations performed within the worksheets consist primarily of taking average or typical annual energy consumption rates and multiplying this rate by the number of units or area of development located on the site. Intermediate calculations are sometimes required to provide input of a specific nature on the worksheets. All calculations can be completed using an ordinary hand calculator.

Chapter 3 of this manual presents each of the seven primary worksheets in detail. Each sub-section of Chapter 3 deals with one worksheet in terms of introducing the concepts and logic underlying the given worksheet, discussing how to use the worksheet and presenting some sample calculations which illustrate this use. The sub-sections also direct the user to the relevant sections of the Catalogue for data as required. Each sub-section is self-contained so that the user need not read sub-sections which are not relevant to a particular development.



Low Rise Apartments

2.6

Data Considerations

The data presented in the Catalogue has been gathered from available literature, particularly literature dealing with current Ontario and Canadian conditions. This data has been supplemented where necessary by calculations of average factors and coefficients. As such, the data represent the best estimates currently available of "average" or "typical" values for Ontario. In the absence of better data, the numbers in the Catalogue can be used with confidence to produce reasonable energy consumption estimates under most planning situations. The accuracy of the energy consumption estimates will increase with the availability of more detailed information and thus increase the potential for identifying differences in consumptions as inputs change. It must be stressed, however, that local conditions can vary considerably from these "typical" values. The extent to which a given value is likely to vary from locality to locality depends upon the information in question. Thus, a general rule for using this manual is: whenever local data is available that can improve or replace the data provided in the Catalogue, this local data should be used.



Row House (99 m²)

2.7

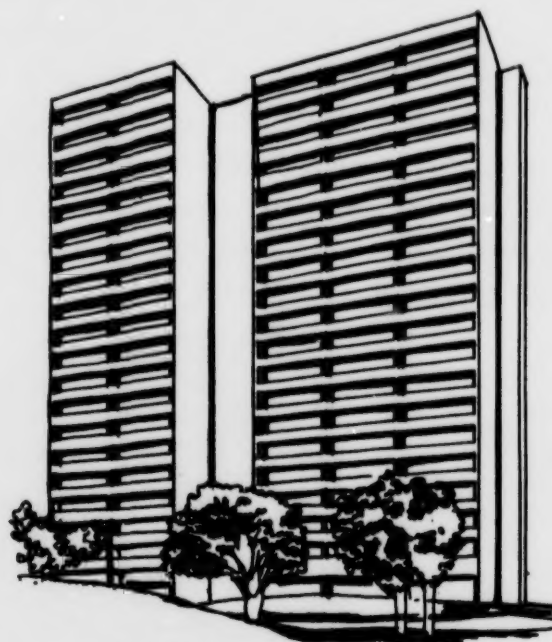
Using the Results of the Analysis

The results of the analysis will identify energy intensive uses and thus focus attention on potential problems at a time when alternatives can be considered. Decision-makers at all levels of government as well as those in the private sector will be provided

with a better understanding of energy consumption. A basis for questioning energy consumption will also likely evolve and hopefully, lead to energy savings in future developments.

2.8 Updating the Data Catalogue

The data provided in the Catalogue will require updating as experience is gained with these types of energy calculations and as new information becomes available through the literature. It is expected, therefore, that periodic updates of the manual or portions thereof will be made.



High Rise Apartments

3.0 ENERGY CONSUMPTION ANALYSIS

3.1 Residential Energy Consumption

3.1.1 Introduction

Energy consumption will vary according to the type of residential uses under consideration. For the purposes of this manual, residential uses have been divided into eight categories: four types of single family dwellings, two types of attached dwellings and two types of apartments. In addition, provision is made in the catalogue to calculate the space heating energy consumption for any building for which the detailed construction characteristics are known.

Residential energy consumption is analyzed under the following categories:

- space heating
- space cooling
- water heating
- lighting and appliances.

In Ontario, space heating is the largest single element of residential energy consumption. This manual provides an analysis of energy consumption based upon both industry-wide average statistics and, if building characteristics are available, a detailed analysis. Detailed information should be used wherever possible in this manual in order to achieve the most accurate estimate of energy consumption. The estimates of energy consumption based on average values can be used when detailed information is not available. The averages upon which these figures are based will be reflected in the accuracy of the results.

The sample calculations shown on the Worksheets have been taken from Case Study 2A and are intended to assist the user in understanding how to fill in the Worksheets.

WORKSHEET NO.1

RESIDENTIAL ENERGY CONSUMPTION

NO. 2A

1 Unit Type	Plan Data		Energy Coefficients (MJ/unit/year)				8 Total of Energy Coefficients (MJ/unit/year)	9 Annual Energy (GJ)
	2 Number of Units	3 Gross Floor Space (m ²)	4 Space Heating	5 Space Cooling	6 Water Heating	7 Lighting and Appliances	4+5+6+7	
Source	User	User	Table A1	Table A7	Table A8	Table A9		2X8+1000

SFLS	87	197	213,000 + 9600 + 24,100 + 21,000	267,700	23,290
SFR	200	116	136,200 + 9600 + 24,100 + 21,000	190,900	38,180
SFSL	200	130	149,700 + 9600 + 24,100 + 21,000	204,400	40,880
SFTS	200	124	136,100 + 9600 + 24,100 + 21,000	190,800	38,160
SD	364	124	125,400 + 7700 + 25,400 + 21,000	179,500	65,338
RH	48	119	100,900 + 7700 + 17,500 + 21,000	147,100	7,061
OTHEF			+ + +		
			+ + +		
			+ + +		
			+ + +		

ALR			+ + +		
AHR			+ + +		
OTHER			+ + +		
			+ + +		
			+ + +		
			+ + +		
			+ + +		
			+ + +		
Total Units	1099	11			

SFLS - Single Family L-Shaped
 SFR - Single Family Regular
 SFSL - Single Family Split Level
 SFTS - Single Family Two Storey
 SD - Semi-detached
 RH - Row House
 ALR - Apartments Low Rise
 AHR - Apartments High Rise

10 Total Annual Residential Energy Consumption = (sum of Items in Column 9) (GJ/Year) 212,909

Enter in Column 3 of Worksheet No. 7

12 Residential Energy Consumption Indicator = $10 \div 11$ GJ/unit/year 194

Enter in Column 6 of Worksheet No. 7

Worksheet No. 1

3.1.2 Using the Residential Energy Consumption Worksheet. Worksheet #1

The following instructions require that the user proceed in the numerical sequence shown on the worksheet. Energy consumption is generally expressed in terms of mega-joules per square metre (MJ/m²) for the components of energy used. A range of average consumption figures is provided in the Catalogue for use when detailed information is not available.

Column 1 - Unit Type

The types of residential units being considered are to be identified by the user. Each unit type is analyzed in a separate row across the worksheet. The user may specify the detailed characteristics of a particular type or select from the six house types discussed in Section A.1 of the Catalogue. For apartment buildings, the user may analyze each building of known characteristics separately or use the average characteristics of a low-rise or high-rise building as described in Section A.1 of the Catalogue. Other unit types can also be used if detailed information and characteristics are available.

Column 2 - Number of Units

The total number of units of each housing type is supplied by the user and entered in Column 2. For houses, the local zoning by-law may give guidance on the number of units permitted in specific areas. If the mix of units is not known, it can often be estimated from data on existing developments in the local area.

Each apartment building should be analyzed on a separate line on the worksheet unless the buildings are of similar shape and size. The number of units for each building is supplied by the user. If the number of units or type of apartment is not known, it can be estimated using local zoning by-laws or by reference to similar buildings in the area.

Worksheet No.1

Column 3 - Floor Space

The user should enter the gross floor area in square metres for each type of unit being analyzed in Column 3. If this information is not known for the proposed development, other local developments can be examined for estimates, or the average standard house sizes listed in Table A2 can be used. If the average apartment size is not available, 100 square metres may be used as an approximation.

Column 4 - Space Heating

The average space heating coefficients for each standard residential unit type expressed in MJ/unit/year are obtained from Table A1 of the Catalogue for most towns in Ontario. Should the area being analyzed not be listed the coefficients for the nearest community should be used. Adjustments to these coefficients to account for variations in unit size, insulation, triple glazing and ventilation can be made through detailed calculations in Table A6 of the Catalogue.

If the construction characteristics of the proposed buildings can be supplied by the user, a detailed calculation of space heating requirements can be made with the information in Section B of the Catalogue.

The resulting space heating coefficient for each residential unit type would then be entered on the residential worksheet in Column 4.

Column 5 - Space Cooling

Energy coefficients expressed in MJ/unit/year for space cooling of each residential unit type are found in Table A7 of the Catalogue and inserted in Column 5. Across Ontario these coefficients will

Worksheet No.1

not vary significantly. However, modification of the coefficients to reflect variation in unit size is advisable where this information is available. Refer to Table A7 for per square metre energy values and adjust coefficients according to unit size.

Column 6 - Water Heating

Energy consumption for hot water heating expressed in MJ/unit/year for each residential unit type is taken from Table A8 and inserted in Column 6.

Column 7 - Lighting and Appliances

The energy consumption for lighting and the use of other domestic appliances expressed in MJ/unit/year for each residential unit type is taken from Table A9 and inserted in Column 7.

Column 8 - Total Unit Energy

The energy coefficients for each residential unit type located in Columns 4 to 7 inclusive are added together and the sum recorded in column 8.

Column 9 - Annual Energy by Unit Type

Total annual energy used in each type of residential unit is obtained by multiplying the number of units (Column 2) by the annual energy consumed per residential unit (Column 8). The result is then divided by 1000 to convert mega-joules (MJ) to giga-joules (GJ) and entered in Column 9.

Line 10 - Total Annual Residential Energy Consumption

This number is the sum of all the annual energy totals (in GJ) for the various unit types. It is obtained by adding all the figures in Column 9. This value is entered in Column 3 of Worksheet No.7.

Worksheet No.1

Box 11 - Total Number of Units

The sum of the number of units of each unit type is obtained by adding Column 2 and placing the result in Box 11.

Line 12 - Residential Energy Consumption Indicator

The Residential Energy Consumption Indicator is calculated by dividing the Total Annual Residential Energy Consumption (Line 10) by the total number of units (Box 11). The units of the indicators are giga-joules per unit per year. This value is also entered in Column 7 of Worksheet No.7.

Worksheet No.2

3.2 Commercial and Institutional Energy Consumption

3.2.1 Introduction

Most commercial and institutional land uses should be analyzed on a building-by-building basis due to the wide range of building types. Offices can often be grouped together because their energy consumption is not very sensitive to internal uses, but other commercial and institutional uses should be considered separately. Commercial activities which use large amounts of energy, such as food stores, may be treated separately from other components of shopping centres and strip retail areas.

Energy consumption is generally expressed in terms of megajoules per sq. metre (MJ/m²) for the components of energy used. A range of average consumption figures is provided in the Catalogue for use when detailed information is not available. It should be noted that the accuracy of these factors will vary due to the wide range of physical characteristics and uses found in institutional and commercial buildings.

3.2.2 Using the Commercial and Institutional Worksheet - Worksheet No.2

The commercial and institutional energy consumption worksheet should be completed sequentially from Column 1 through Column 11. Where information is to be provided by the user or from the Catalogue, it is noted under the column headings. The following instructions require that the user proceed in the numerical sequence shown on the worksheet.

Column 1 - Land Use Type

The type of land use must be provided by the user. Each commercial or institutional land use is to be analyzed as a separate row on the worksheet.

WORKSHEET NO. 2

COMMERCIAL AND INSTITUTIONAL ENERGY CONSUMPTION

NO. 2A

1	2	Energy Coefficients (MJ/m ² /Year)						10	11	
Land Use Type	Gross Floor Space (m ²)	3	4	5	6	7	8	9	Total of Energy Coefficient	Annual Energy (GJ)
User	User	Space Heating	Space Cooling	Lighting	Fans & Pumps	Water Heating	Other Energy	Process Power	Table C-1	2 X 10 ÷ 1000
		Table C-1	Table C-1	Table C-1	Table C-1	Table C-1	Table C-1	Table C-1	Sum 3-9	

Office

General	1500								1000	1500

Retail

Food	500								3600	1800
General	1000								1900	1900
Gas Station	250								2600	650

Institutional

2 Schools	3000								870	2610
Church	1000								870	870

Total Area (m ²)	7250	12
------------------------------	------	----

Total
13 Commercial and Institutional Energy Consumption (GJ/Year) =
(Sum of items in column 11)

9330

Enter in Column 3 of Worksheet No. 7

14 Commercial Institutional Energy Consumption Indicator =
13 ÷ 12

GJ/m²/year

1.3

Enter in Column 6 of Worksheet No. 7

Worksheet No.2

Should the development proposal being analyzed not provide specific information on the type of commercial and institutional uses to be expected, guidance may be found in local sources such as the Official Plan or the Zoning By-law. Examination of similar developments in other parts of the urban area may provide appropriate information.

Column 2 - Floor Space

The total gross floor space, expressed in m^2 for each commercial and institutional use must be supplied by the user and placed in Column 2. If information for the proposed development is not available, estimates of gross floor space may be obtained from the coverage requirements of the zoning by-law, the general requirements of the Official Plan, or information contained in Table C2 of the Catalogue.

If only gross leaseable floor area is available for commercial facilities then these areas must be multiplied by 1.05 for strip retail commercial and 1.25 for shopping centres to convert them to gross floor areas.

Columns 3-9 - Energy Coefficients

For the most accurate estimates of energy consumption, the energy coefficients expressed in MJ/m^2 should be obtained from local sources such as the developers, architects, or records of use for similar buildings. If detailed information is not available for all coefficients, estimates may be used from the average values provided in Table C1 of the Catalogue. If no accurate estimates for any of the coefficients are available, the total unit energy estimates from Table C1 of the Catalogue may be entered directly into Column 10.

Worksheet No.2

Column 10 - Total Energy Coefficients

The energy coefficients for items 3 to 9 inclusive are added together and this value entered in Column 10 to give the total energy coefficients for each commercial and institutional land use. If detailed information is not available for all coefficients, estimates may be used from the average values provided in Table C1 of the Catalogue. If no accurate estimates for any of the coefficients are available, the total unit energy estimates from Table C1 of the Catalogue may be entered directly into Column 10.

Column 11 - Annual Energy by Type

The total annual energy used in each type of commercial or institutional development is the product of the total unit energy per m^2 (Column 10) and the gross floor space (Column 2). To convert to giga-joules (GJ) the result is divided by 1,000.

Box 12 - Total Gross Floor Area

The total gross floor area in square metres is obtained by adding all values in Column 2 and entering the answer in Box 12.

Item 13 - Total Annual Commercial and Institutional Energy Consumption

This number is the sum of all the annual energy totals for the various land uses expressed in GJ. It is obtained by adding all the figures in Column 11. This value is entered in Column 3 of Worksheet No.7.

Worksheet No.2

Line 14 - Commercial and Institutional Energy
Consumption Indicator

The Commercial and Institutional Energy Consumption Indicator is calculated by dividing the Total Annual Commercial and Institutional Energy Consumption (Line 13) by the Total Gross Floor Area (Box 12). The result in GJ/m²/year is entered in Line 14 and Column 6 of Worksheet No.7.

Worksheet No.3

3.3 Industrial Energy Consumption

3.3.1 Introduction

As industrial energy consumption is rarely related to land use factors, the level of energy consumption is often dictated by the nature of the industrial process rather than the type of building which is occupied or the utilization of the land.

Worksheet No. 3 considers industries in light, medium and heavy groups. The 18 major Standard Industrial Classification (SIC) groups are then split between the three major categories. The energy use coefficients provided for Worksheet No. 3 are based on the relationship between land area, workers and the energy use per worker as presented in Section D of the Catalogue.

In analyzing the industrial component of a new development the user should keep in mind the inherent differences and difficulties associated with this type of land use. The process-oriented nature of industrial energy consumption raises two problems:

1. It is not possible to estimate energy requirements of a particular industry using basic land use variables such as number of units or amount of floor space.
2. The level of industrial energy consumption is not sensitive to regulation by the traditional planning tools except by outright prohibition of certain energy intensive forms of industry.

WORKSHEET NO.3 INDUSTRIAL ENERGY CONSUMPTION

NO. 2A

1 Industrial Category	2 Area	3 Employment Density	4 Employment	5 Energy Coefficient	6 Total Annual Energy Consumption
	ha	Workers/ha	Workers	MJ/Worker	GJ
Table D1	User	Table D2	User or 2 x 3	Table D3	4x5 - 1000

Light Industry	12.11	40	485	74,660	36,165
Knitting					
Clothing					
Printing and Publishing					
Electric Products					
Miscellaneous					

Medium Industry					
Food and Beverage					
Plastic and Rubber					
Leather					
Textiles					
Wood					
Furniture and Fixtures					

Heavy Industry					
Paper and Allied Products					
Primary Metals					
Metal Fabricating					
Machinery					
Transport Equip					
Non Metallics and Mineral Products					
Chemicals					

7 Total Lot Area	12.11				
------------------	-------	--	--	--	--

8	Total Annual Industrial Energy Consumption = (Sum of Items in column 6) (GJ/Year)	36,165
---	--	--------

Enter in Column 3 of Worksheet No. 7

9	Industrial Energy Consumption Indicator 8 ÷ 7 (GJ/ha/year)	2986
---	---	------

Enter in Column 6 of Worksheet No. 7

Worksheet No.3

Additional information available in Table D4 in Section D of the Catalogue permits the interested user to divide the total energy use for each category into the following end use groups:

- process
- space heating
- lighting
- make-up air
- motors and turbines
- transportation

3.3.2 Using the Industrial Worksheet - Worksheet No. 3

The following instructions require that the user proceed in the numerical sequence shown on the worksheet.

Column 1 - Industrial Category

The category of industry found in the new development must be supplied by the user. Each industrial category is analyzed on a separate line on the worksheet.

Should detailed information on the type of industry to be built not be available, the user may be able to estimate the composition of industrial land uses by reference to the list of permitted uses in the local zoning by-laws, or by comparison to similar industrial areas.

If a detailed breakdown by SIC Group is not available the user may categorize development as light, medium or heavy and use the general rows provided. Table D1 in the Catalogue relates the industrial categories used in this worksheet to the SIC groups.

Column 2 - Lot Area¹⁾

The total lot area to be used by each industrial category, expressed in hectares, must be entered by the user in Column 2. Should no detailed information of the proposed development be available, the user may wish to refer to the local Official Plan, Zoning By-law, Secondary Plan, or similar industrial areas to estimate the total area of each industrial category.

Column 3 - Employment Density

The user should insert the number of employees per hectare in Column 2 that reflect local industrial conditions. Should this information not be available to the user then Table D2 in the Catalogue provides average employee per hectare values that can be inserted in Column 2.

Column 4 - Employment

Should employment statistics be available for the industrial development proposed by either major group (light, medium or heavy) or by SIC classification they should be entered in Column 4. If this information is not available an estimate of the total employment can be obtained by the product of the area (Column 2) and the employment density by group (Column 3). The result is entered in Column 4.

Column 5 - Energy Use Coefficients

Energy use coefficients expressed in MJ/Worker for each major industrial category may be found in Table D3. Should the user not be able to identify specific industries Table D3 provides coefficients for light, medium and heavy industrial land use based on the average of the estimates for the SIC groups at each level.

1) Lot area is defined as the total area, in hectares, of the development in each SIC category or in each industrial group (light, medium and heavy).

Worksheet No.3

Column 6 - Total Annual Energy Consumption
by Industrial Category

The total annual energy consumption for each industrial category, expressed in GJ, is obtained by multiplying the estimated employment (Column 4) by the energy use coefficient (Column 5). Enter the result in Column 6.

Box 7 - Total Lot Area

The Total Lot Area in hectares is obtained from the sum of all values in Column 2. Enter the result in Box 7.

Item 8 - Total Annual Industrial Energy Consumption

This result is the sum of the annual energy consumption for all the industrial categories. It is obtained by adding all the figures in Column 6. Enter this value in Column 3 of Worksheet No.7.

Line 9 - Industrial Energy Consumption Indicator

The Industrial Energy Consumption Indicator is calculated by dividing the Total Annual Industrial Energy Consumption (Line 8) by the Total Lot Area (Box 7). The result in GJ/ha/year is entered in Line 9 and Column 6 of Worksheet No.7.

Worksheet No.4

3.4 Transportation Energy Consumption

3.4.1 Introduction

This section describes the use of Worksheet No.4 to calculate the transportation energy consumption associated with automobile and transit travel generated by and attracted to a given development site. The worksheet computes the total energy consumption associated with all person trips by automobile and public transit to, from and within the development site.

The worksheet does not compute indirect transportation energy consumption (i.e., energy consumption associated with the construction of the roadways and vehicles) nor does it compute the energy consumption associated with commercial vehicle movements. Commercial vehicle trip generation is dominated by inter-city rather than intra-urban movements and hence energy consumption is only marginally affected by site location and design.

In using the transportation worksheet it is important to keep in mind three important considerations:

1. The characteristics of travel (and, hence, of transportation energy consumption) are highly dependent on local conditions. Local data on travel should be used whenever possible in place of the "typical" data provided in Section E of the Catalogue.
2. The analysis performed in the transportation worksheet is not appropriate for investigating small scale design issues such as the impact of minor variations in street layouts on transportation energy consumption.

Worksheet No.4

3. Care must be taken in using the results generated by this worksheet to compare alternative site designs and/or locations. In particular, it is not possible to determine the net effect of a new development upon the overall regional transportation energy consumption.

The method used in the worksheet is quite simple by conventional transportation planning standards, and is designed to minimize the data and calculations required to generate a useful energy consumption estimate. The worksheet estimates the total number of trips generated by the various land uses within the development site, estimates the average trip length associated with these trips, "splits" the trips between the automobile and transit modes, and computes the energy consumption by both of these modes based on the total passenger-kilometres of travel which has been computed for each mode.

3.4.2 Using The Transportation Energy Worksheet - Worksheet No.4

Worksheet No.4 is divided into five parts which correspond with the five major calculations:

- A. Trip productions
- B. Trip attractions
- C. Calculation of internal and external trips
- D. Calculation of Passenger - Kilometres of Travel by mode
- E. Calculation of total energy consumption by mode.

The following sections assume the user is completing the worksheet in the order of the numbered items on each sheet.

WORKSHEET NO.4

TRANSPORTATION ENERGY CONSUMPTION

NO. 2A

A. Trip Productions

	1	2	3	4	5
Dwelling Unit Type	No. of Units	Trips/ Unit	Annual Trips	Persons/ D.U.	Total Persons
Source	User	Tab. E1	1 X 2	Tab. E4	1 X 4
Single Family Detached	687	3588	2,464,956	3.5	2405
Single Family Attached	412	2912	1,199,744	3.5	1442
Low - Rise Apartment					
High Rise Apartment					

6 Total Annual Trip Productions =

3,664,700

7 Population =

3847

B. Trip Attractions

8	9	10	11
Land Use Activity (Excluding Local Uses)	Floor Space (m ²) or Employees	Average Trips Per Employee or Unit Area Trips/m ² /Year	Annual Trips
Source	User	Tables E2 & E3	9 X 10
1 Light Industrial	72,660 m ²	17	1,235,220
2 School	500 students	260 trips/student	130,000
3			
4			
5			
6			
7			
8			

12

Total Annual Trip Attractions =

1,365,220

WORKSHEET NO.4 CON'T TRANSPORTATION ENERGY CONSUMPTION

NO. 2A

C. Internal and Total Trips

		Source	
13	Regional Population	User	410,045
14	Internal Person Trips	$(12 \times 7) \div 13$	12,808
15	Total Person Trips	$6 + 12 - 14$	5,017,112

D. Passenger - Kilometres of Travel

16	Average Trip Length (KM)	Fig. E1 and Table E5	8.4
17	Total Person - Kilometres	15×16	42,143,741
18	Average % of Trips by Transit	Table E10	0.12
19	Total Transit Passenger - KM	17×18	5,057,249
20	Total Automobile Person - KM	$17 - 19$	37,086,492

E. Energy Consumption

21	Energy Intensity (MJ/Pass. - KM)	Table E7	1.00
22	Transit Energy Consumption (MJ/Year)	19×21	5,057,249
23	Average Automobile Occupancy	Table E8	1.4
24	Average Auto Energy Consumption (MJ/veh. - KM)	Table E9	6.4
25	Automobile Energy Consumption (MJ/Year)	$20 \div 23 \times 24$	169,538,249

26	Total Annual Transportation Energy (GJ/Year)	$(22 + 25) \div 1000$	174,595
----	--	-----------------------	---------

Enter in Column 3 of Worksheet No. 7

F. Energy Consumption Indicator

27	Total Residential Gross Floor Area (m ²)	Sum of Column 2 x 3 in Worksheet No. 1	141,987
28	Total Inst./Com./Industrial GFA (m ²)	Sum of Column 9	73,160
29	Total Gross Floor Area (m ²)	$27 + 28$	215,147
30	Transportation Energy Consumption Indicator GJ/m ² /year	$26 \div 29$	0.81

Enter in Column 6 of Worksheet No. 7

Worksheet No.4

A. TRIP PRODUCTIONSColumn 1 - Number of Units

The user must provide the number of units for each residential dwelling type and insert in Column 1. The number of units can be obtained by combining the values in Column 2 on Worksheet No. 1.

Column 2 - Trips Per Unit

The annual number of person trips per unit is obtained from Table E1 and inserted in Column 2.

Column 3 - Annual Trips

The annual total of person trips for each dwelling unit type is obtained by multiplying the number of units (Column 1) by the person trips per unit (Column 2).

Column 4 - Persons Per Dwelling Unit

The number of persons per dwelling unit for each type of unit should be obtained from local or census information. If no local data is available, the values in Table E4 of the Catalogue may be used as estimates.

Column 5 - Total Persons

The total number of people living in each dwelling type is obtained by multiplying the number of units (Column 1) by the persons/unit (Column 4).

Box 6 - Total Annual Trip Productions

The total number of trips produced by the new development is the sum of all the values in Column 3.

Box 7 - Total Population

The total population of the proposed development is the sum of all the values in Column 5.

Worksheet No.4

B. TRIP ATTRACTIONSColumn 8 - Land Use Activities

The land use activities for trip attractions are all the activities in the proposed development listed in the commercial, institutional and industrial worksheets with the exception of convenience commercial, local offices and elementary schools where most of the trips will be attracted from the proposed development. These exceptions are due to the fact that these trips will likely be significantly shorter than the average trip length and may be accomplished by foot or bicycle.

Column 9 - Floor space or Employees

The user must supply the floor space (m^2) for each land use activity. Commercial and institutional floor space can be obtained from Column 2 on Worksheet No.2. Industrial floor space should be obtained from the developer or estimated using the coverage provisions of the local zoning by-law. If floor space is not available, the number of employees may be used.

Column 10 - Annual Trips per Employee or Unit Area

Table E2 gives typical trip attraction rates per m^2 of floor space and Table E2A gives these rates on an employee basis. The annual trip attraction rates should be used. Retail commercial rates should be obtained from Table E3 after reference to explanatory notes.

Column 11 - Annual Trip Attractions

The annual trip attractions for each land use are calculated by multiplying floorspace (9) by trips/ m^2 (10) or the appropriate factors for employees.

Box 12 - Total Annual Trip Attractions

This result is obtained by adding all the values in Column 11.

Worksheet No.4

C. INTERNAL TRIPS AND TOTAL TRIPS

Line 13 - Regional Population

The regional population is considered to be the population of the immediate surrounding area to which residents or employees of the new development will normally travel on a daily basis or from which trips will be attracted to the new development. This value must be provided by the user and can normally be obtained from the local planning office. Where data is not available an estimate of the population of the town where the development under study is located can be used. This value is entered in Line 13.

Item 14 - Internal Trips

The ratio of the population of the proposed development to the total regional population is used to estimate the fraction of total trip attractions which are internal in nature, as very limited regional information is available.

The number of internal trips is estimated by multiplying the total trip attractions (Box 12) by the site population (Box 7) and dividing this result by the regional population (Line 13).

Line 15 - Total Person-Trips

The total number of person-trips generated by the development is the result of trip productions (Box 6) plus total annual trip attractions (Box 12) less internal trips (Line 14).

D. PASSENGER-KILOMETRES OF TRAVEL

Line 16 - Average Trip Length

The average trip length (in kilometres) is obtained from Figure E1 and Table E5 if local data from a transportation plan is not available. If the subject community is not on these lists, Table E6 provides a list of urban characteristics to permit the user to select a similar community for purposes of estimation.

Worksheet No.4

Line 17 - Total Person-Kilometres Travelled

The total number of person-kilometres travelled per year is calculated by multiplying the total number of person-trips (Item 15) by the average trip length (Item 16).

Line 18 - Average Fraction of Trips by Transit

The percentage of total trips taken by public transit should be obtained from local transportation data. If this data is not available, it may be estimated using Table E10. Communities with no public transit system will insert a value of 0.0.

Line 19 - Total Transit Passenger-Kilometres

This value is obtained by multiplying the average fraction of transit trips (Line 18) by the total number of person-kilometres (Line 17).

Line 20 - Total Automobile Passenger-Kilometres

This value is obtained by subtracting the number of transit passenger kilometres (Line 19) from the total person-kilometres travelled (Line 17).

E. ENERGY CONSUMPTIONLine 21 - Transit Intensity

Transit energy intensity per passenger-kilometres is obtained from Table E7, if local data is not available.

Line 22 - Transit Energy Consumption

Transit Energy Consumption (MJ/year) is obtained by multiplying the total number of transit passenger-kilometres (Item 19) by the energy per passenger-kilometre figure (Line 21).

Worksheet No.4

Line 23 - Average Automobile Occupancy

Average automobile occupancy for all trips should be obtained from local data or Table E8 in the Catalogue.

Line 24 - Average Automobile Energy Consumption

The average automobile energy consumption expressed in MJ/vehicle-kilometre is found in Table E9 of the Catalogue.

Line 25 - Automobile Energy Consumption

The total number of automobile passenger-kilometres (Line 20) must be divided by the average car occupancy (Line 23) and then multiplied by the average automobile fuel consumption information (Line 24) to obtain the total automobile energy consumption.

Line 26 - Total Annual Transportation Energy Consumption

The total annual transportation energy consumption (in GJ/year) is the sum of total transit energy (Line 22) and automobile energy consumption (Line 25) divided by 1,000 to convert to giga-joules. This value is then placed in Column 3 of Worksheet No.7.

F. ENERGY CONSUMPTION INDICATORSLine 27 - Total Residential Gross Floor Area

The Total Residential Gross Floor Area in m² is obtained by multiplying the number of units in each unit type category (Column 2 - Worksheet No.1) by the appropriate gross floor area (Column 3 - Worksheet No.1) and placing the sum in Line 27.

Worksheet No.4

Line 28 - Total Industrial/Commercial/Institutional
Gross Floor Area

The area in square metres of those uses that are considered trip attractors (as entered in Column 8) are summed and the result placed in Line 28.

Line 29 - Total Gross Floor Area

The total gross floor area is obtained by adding the values in Lines 27 and 28.

Line 30 - Transportation Energy Consumption Indicator

The transportation energy consumption indicator is obtained by dividing the total annual transportation energy (Line 26) by the total gross floor area (Line 29). This value in GJ/m²/year is entered in Line 30 and Column 6 of Worksheet No.7.

Worksheet No.5

3.5 Construction Energy Consumption

3.5.1 Introduction

The purpose of the construction energy worksheet is to estimate annualized energy consumed through construction of buildings and services and site preparation. To facilitate comparison with other annual energy figures this estimate is translated into an annual equivalent based on the life of the facility. The method proposed is a simplified one as construction energy consumption is extremely small when compared to space heating and transportation energy consumption.

As in the other worksheets, data is provided in the Catalogue so that calculations can be made using average values. If local figures are available, then they should be used instead of those provided in Section F of the Catalogue.

3.5.2 Use of Construction Energy Worksheet - Worksheet No.5

The construction energy worksheet should be completed sequentially from Column 1 through Box 15. Information to be provided by the user should be available from Worksheets 1 through 4. The following instructions require that the user proceed in the sequence as shown on the worksheet.

Column 1 - Land Use Type

This information is standard unless the proposed development has a unique component. It is generally expected that most land uses will fit within one of the types listed for which energy data is readily available. Should the user have a component of the proposed development that does not fit then energy consumption values must also be provided. An estimate might be made based on similar structures or information from architects or engineers.

WORKSHEET NO.5

CONSTRUCTION ENERGY CONSUMPTION

NO. 2A

1	2	3	4	5	6
Land Use Type	Gross Building Area m ² (User)	Energy per m ² (MJ/m ²) Table F1	Energy by Type (MJ) 2x3	Project Life Years Table F2	Annual Energy MJ/Year 4-5

Construction of Buildings

Residential: Single Family	91,139	8.1	738,226	50	14,765
Residential: Two-Four Family	50,848	7.2	366,106	50	7,322
Residential: Apartment					
Commercial Office	1,500	18.9	28,350	50	567
Commercial Retail	1,750	10.9	19,075	30	636
Educational	3,000	15.9	47,700	50	954
Hospitals					
Industrial	72,660	11.2	813,792	20	40,690
Other church	1,000	15.9	15,900	50	318
Total Gross Building Area	221,897	Total Annual Building Construction Energy 7 (MJ/Year)			65,252 → 65,252

8	9	10	11	12	13
Major Service Types	Length of Service (M) (User)	Energy/m (MJ/m) Table F3	Energy by Type (MJ) 9x10	Project Life Years Table F2	Annual Energy MJ/Year 11+12

Construction of Services

Roads	11,300	3.0	33,900	25	1356
Water	11,300				
Sanitary Sewers	11,300				
Drainage Piping	11,300				
Drainage Ditching	0				
Sidewalks Walkways	11,300				
Contingencies	11,300				
All Piped Services	11,300	5.64	63,732	100	637

14 Total Annual Service Construction Energy (MJ/Year) 1993 → 1993

15 Total Annual Construction Energy Consumption (7 + 14) - 1000 GJ/Year 67

Enter in Column 3 of Worksheet No. 7

16 Construction Energy Consumption Indicator (15 + Total Gross Building Area) GJ/m²/year .0003

Enter in Column 6 of Worksheet No. 7

Worksheet No.5

Column 2 - Gross Building Area

Total gross areas for each building type are entered in Column 2 in square metres. This information must be provided by the user and can be calculated using data available from Worksheets 1, 2, 3, and 4.

Column 3 - Energy Consumption

The total embodied¹⁾ and direct²⁾ energy consumption for the construction of new buildings in each land use type, expressed in MJ/m² is entered in Column 2. This information can be found in Table F1 of the Catalogue.

Column 4 - Energy Consumption By Type

The total energy consumed by the construction of each land use type is calculated (Column 2 x Column 3) and entered in Column 4. These values are expressed in MJ.

Column 5 - Project Life

The estimated useable life span for each land use type is entered in Column 5. Should data not be available from the architect, builder or developer refer to Table F2 of the Catalogue for estimated life span of different land use types.

Column 6 - Annual Energy Consumption by Type

The annual energy consumed in the construction of each land use type, expressed in MJ/Year, is calculated (Column 4 ÷ Column 5) and entered in Column 6. This calculation spreads the actual energy consumed over the expected life of the buildings.

-
- 1) Embodied energy is the energy required to obtain the basic construction materials.
 - 2) Direct energy is the energy required to construct the buildings.

Worksheet No.5

Line 7 - Total Annual Building Construction Energy

The total annual building construction energy of the buildings in the proposed development is obtained by the sum of all figures in Column 6.

Column 8 - Major Service Types

Each of the major services that are generally required in a fully serviced development are listed in Column 8.

Column 9 - Length of Service

The total length, in metres, of each service located in the development is entered in Column 9. If servicing has been analyzed the engineer responsible should be able to provide accurate lengths for each service. Should this information not be available it is recommended that all services, including contingencies, should assume a length similar to the roadway. This value should be entered in the line labelled 'All Piped Services'. Contingencies for adjustments to standard municipal services and extra site services are included to account for additional energy consumption resulting from such factors as difficult topographic conditions or a high ground watertable.

Column 10 - Energy Consumption

The total energy consumption for the construction of each service, expressed in MJ/m, is entered in Column 10. This information can be found in Table F3 of the Catalogue. If all piped services are the same length refer to the notes to Table F3.

Column 11 - Energy Consumption by Type

The total energy consumed by the construction of each service, expressed in MJ, is calculated (Column 9 x Column 10) and entered in Column 11.

Worksheet No.5Column 12 - Project Life

The estimated useable life span for each service is entered in Column 12. Should an estimate of the projected life span of each service not be available from the developers or design engineers, an estimate of 25 years for roads and 100 years for all piped services and contingencies can be used (Table F2).

Column 13 - Annual Energy Consumption by Service

The annual energy consumed in the construction of roads and services, expressed in MJ/Year, is calculated (Column 11 ÷ Column 12) and entered in Column 13. This calculation spreads the actual energy consumed over the expected life of the roads and services.

Line 14 - Total Annual Service Construction Energy

The total annual service construction energy of the roads and piped services in the proposed development is obtained by the sum of all figures in Column 13.

Box 15 - Total Annual Buildings and Service Construction Energy Consumption

The total annual building and service construction energy consumption, expressed in GJ/Year, is obtained by the sum of Line 7 and Line 14 divided by 1,000 to convert from MJ to GJ. This value is also entered in Column 3 of Worksheet No.7.

Box 16 - Construction Energy Consumption Indicator

To obtain the Construction Energy Consumption Indicator in GJ/m²/year the Total Annual Building and Service Construction Energy Consumption (Box 15) is divided by the Total Gross Building Area (sum of Column 2). This value is entered in Box 16 and Column 6 of Worksheet No.7.

Worksheet No.6

3.6 Operation of Services Energy Consumption

3.6.1 Introduction

The operation of services worksheet estimates the annual energy consumed to provide all land uses with basic services. These services include water treatment, sewage treatment and solid waste disposal. A contingency factor is used to account for services such as fire and police which consume energy on an irregular basis. It should be noted that no estimate of snow removal energy consumption has been made as these costs vary widely due to location, climatic variations and levels of snow removal service.

3.6.2 Use of the Operation of Services Energy Worksheet - Worksheet No.6

The operation of services energy worksheet should be completed sequentially from Column 1 through Box 7. Information to be provided by the user is available from Worksheets 1 through 4 and the Catalogue. The following instructions require that the user proceed in the sequence as shown on the worksheet.

Column 1 - Land Use Type

This information is standard unless the proposed development has a unique component. It is generally expected that most land uses will fit within one of the types listed. Inclusion of unique land uses will require that the user provide basic service energy consumption values. This value could be calculated based on information from similar buildings or structures.

Column 2 - Number of Units or Area

The number of residential units for each residential type or the gross area in square metres of commercial development are entered in Column 2. For schools, a factor obtained by dividing the

WORKSHEET NO.6

OPERATION OF SERVICES' ENERGY CONSUMPTION

NO. 2A

1	2	3	4
Land Use Type	Number of Units or Area	Service Energy Factor	Annual Energy Consumption
Source	Worksheets 1,2, and 3	Table G5	2x3

Residential Single Family	687 units	2000 MJ/unit	1,374,000
Residential Two-Four Family	412 units	1500 MJ/unit	618,000
Residential Apartment			
Commercial - Office	1500 m ²	11 MJ/m ²	16,500
Commercial - Retail	1750 m ²	52 MJ/m ²	91,000
Educational	2 schools (1000 stud)	200,000 MJ/1000 stud.	200,000
Hospital			
Industrial - Light	12.11 ha.	55,000 MJ/ha.	666,050
Industrial - Heavy			
Other 1 church	1000 m ²	11 MJ/m ² (assume office)	11,000

5 Sub Total
(Sum of Column 4)

2,976,550

6 Energy Consumption Contingency Factor
(See Section 3.6.2)

1.15

7 Total Annual Energy Consumption
for Operation of Services (5x6) ÷ 1000 GJ/Year

3423

Enter in Column 3 of Worksheet No. 7

8 Operation of Services Energy Indicator
(7 + Sum of Column 2 Worksheet No. 5) GJ/m²/year

0.015

Enter in Column 6 of Worksheet No. 7

Worksheet No.6

number of students by 1,000 is entered in Column 2 (e.g., 800 students means a factor of 0.8; 1,400 students means a factor of 1.4). The energy consumption factor for hospitals is obtained by dividing the number of beds by 500. Land designated for industrial development is expressed in hectares and the gross area entered in Column 2.

Column 3 - Average Annual Service Energy Factors

An average annual service energy factor has been calculated for each of the standard land use types. These values can be found in Table G5 and have been calculated using average generation rates and energy consumption data. If the user has local data or updates the figures in Section G of the Catalogue then the Basic Energy Factors calculated in Table G5 MUST be revised accordingly.

Column 4 - Annual Energy Consumption

The annual energy consumed in the operation of services for each of the standard land use types, expressed in MJ/Year is calculated (Column 2 x Column 3) and entered in Column 4.

Box 5 - Sub-Total of Annual Energy Consumptions

This sub-total is obtained by summing all figures in Column 4 and entering the result in Box 5.

Box 6 - Energy Consumption Contingency Factor

An energy consumption contingency factor is used to account for variations in local circumstances and the irregular energy consumed by services which precludes an estimation of energy consumed. To account for this consumption the total energy consumption by other services is increased by a factor of 1.15 (15% increase).

Worksheet No.6

Box 7 - Total Annual Energy Consumption for Operation of Services

The total annual energy consumption for operation of services for the proposed development is calculated (Box 5 x Box 6) and then divided by 1,000 to convert to GJ/Year. The resulting value is entered in Line 7 and Line 10 of Worksheet No.7.

Box 8 - Operation of Services Energy Indicator

The Operation of Services Energy Indicator is calculated by dividing the Total Annual Energy Consumption for Operation of Services (Box 7) by the Total Gross Building Area (sum of Column 2 - Worksheet No.5). Enter this value in Box 8 and Column 6 of Worksheet No.7.

Worksheet No.7

3.7 Total Energy Consumption - Summary

Sections 3.1 through 3.6 describe the procedure to calculate the energy consumed in the construction, maintenance and operation of new development. Worksheet No.7 summarizes the results of Worksheets 1 through 6 providing an opportunity to compare the energy required for the different components of a new development and their relative values. A summary of the Energy Indicators is also provided for ease of comparison with other alternatives

**3.7.1 Use of the Energy Consumption Summary Worksheet -
Worksheet No.7**

For each worksheet (Column 1) the total annual energy consumed, expressed in GJ/Year, is found (Column 2) and entered in column 3. The percent distribution of these values is then calculated (Column 4). The total annual energy consumption of the proposed development is obtained by summing the values in Column 3 and entering the result in Line 11. The source of each of the Energy Indicators is shown in Column 5 and the value of each indicator shown in Column 6.

3.7.2 The Total Annual Energy Consumption of Proposed Development

The value entered in Line 11 of Worksheet No.7 is the final result of the calculations performed in Worksheets 1 through 7. Given all the factors that must be considered and recognizing that average figures have been used in most cases, this number represents a reasonable estimate of the annual energy that will be consumed by the proposed development over its lifetime. Should the user wish to convert giga-joules (GJ) to other units, a table of conversion is provided at the beginning of this manual. It should be noted that each category listed in Worksheet No.7 represents, in reality, a combination of fuels. Thus, for example, conversion of transportation energy to litres of gasoline does not consider use of diesel or electricity as fuels. For this reason conversion is NOT recommended.

WORKSHEET NO.7

ENERGY CONSUMPTION - SUMMARY

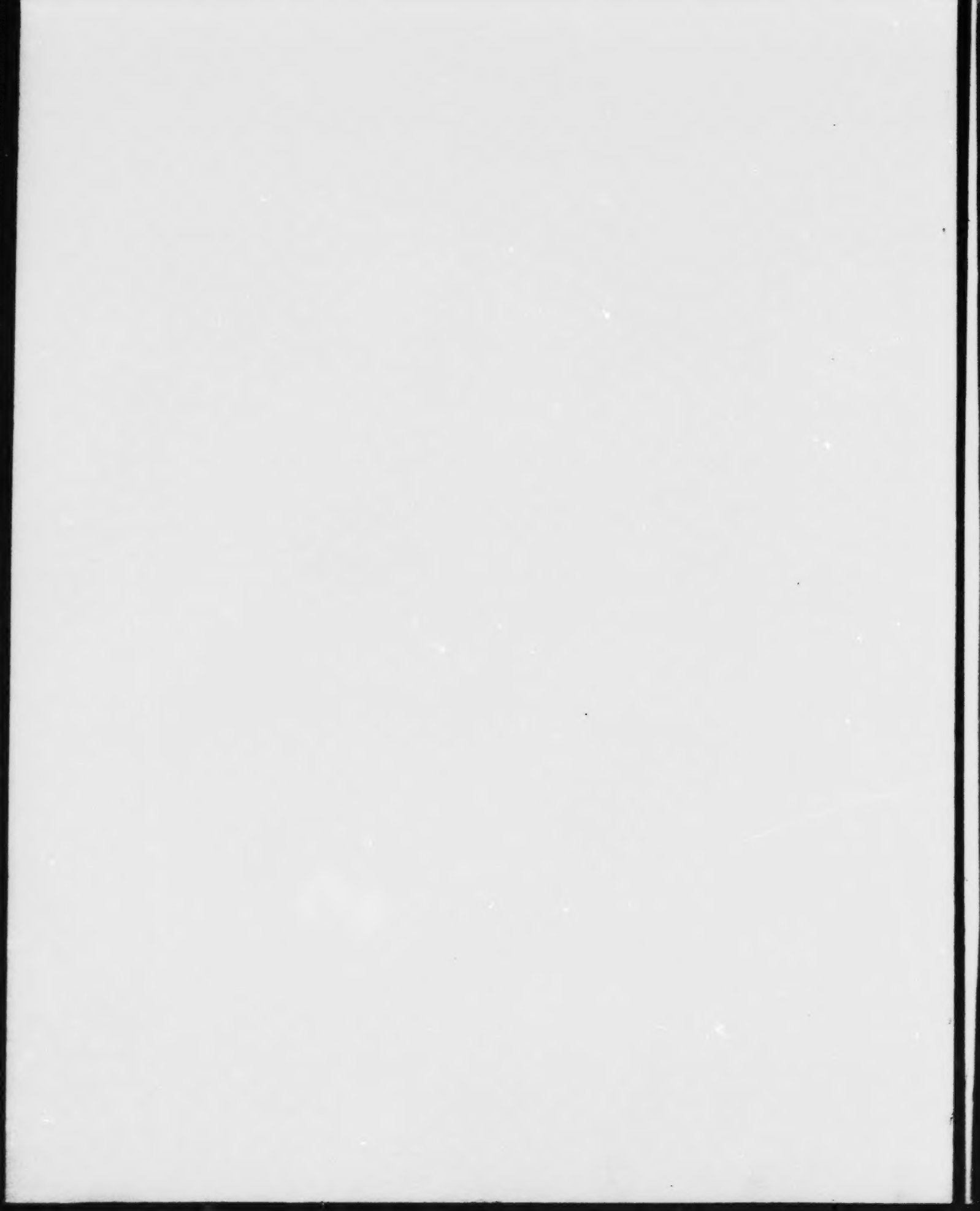
NO. 2A

1		2	3	4	5	6
Line No.	Category	Worksheet Source	Total Annual Energy Consumption GJ/year	Distribution % (Total of 100)	Worksheet Source (Indicators)	Energy Consumption Indicators

7	Residential	No. 1 Line 10	212,909	48.8	No. 1 Line 12	194 GJ/Unit/year
8	Commercial and Institutional	No. 2 Line 13	9,330	2.1	No. 2 Line 14	1.3 GJ/m ² /year
9	Industrial	No. 3 Line 8	36,165	8.3	No. 3 Line 9	2986 GJ/ha/year
10	Transportation	No. 4 Line 26	174,595	40.0	No. 4 Line 30	0.81 GJ/m ² /year
11	Construction	No. 5 Line 15	67	-	No. 5 Line 16	0.003 GJ/m ² /year
12	Operation of Services	No. 6 Line 7	3,423	0.8	No. 6 Line 8	0.015 GJ/m ² /year

13 Total Annual Energy Consumption
of Proposed Development
(Sum of Column 3)

436,489
GJ/year



4.0 CASE STUDIES

4.1 Introduction

The following case studies illustrate the use of the worksheets and Data Catalogue in three examples of proposed new development. The examples are located, for the purposes of discussion, in three communities of different population sizes - Orillia, Hamilton and Kingston. The examples are based on projects now under development, but not in these three communities.

Two alternatives for each case study are analyzed. For each case study the assumptions and calculations for both alternatives are presented together to enable the user to easily compare the effects of the different land use assumptions as each worksheet is completed.

The complexity of the calculations increases as the user proceeds from Case Study No.1 through Case Study No.3. In addition, more local data is used in each successive study to demonstrate areas where the user could substitute more accurate local information in lieu of the average values provided in the Catalogue.

4.2

Case Study One - A Residential Subdivision

This case study presents two alternatives for a residential subdivision of approximately 24 ha (60 acres). Alternative 1A consists mainly of single detached homes and Alternative 1B contains semi-detached houses. For the purposes of this study it is presumed that the proposed development is located in the outskirts of Orillia, and that local detailed data is not available. Thus average values from the Catalogue have been used in the Worksheets.

The property to be analyzed is located at the intersection of a minor arterial and a major arterial road, and mainly consists of abandoned agricultural land. The site slopes slightly to the south and an intermittent watercourse in its centre has been incorporated into both designs as a local park. Both designs have a similar local street pattern, so that any difference in energy consumption should be caused by the change in unit density and housing mix.

4.2.1

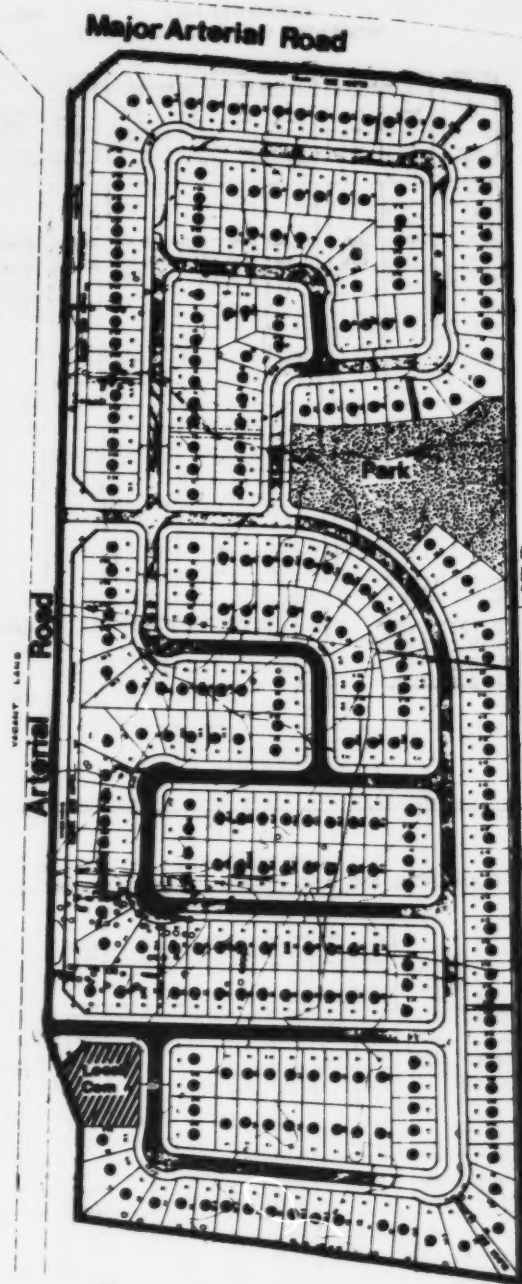
Land Uses

Alternative 1A contains 314 single family detached lots while Alternative 1B contains 282 semi-detached lots. Both plans have a site for a local commercial use, as shown in Figure 4.1. The land use information which would be available to the user from the draft plans of subdivision includes:

<u>Land Use</u>	<u>Alternative 1A</u>		<u>Alternative 1B</u>	
	<u>Units</u>	<u>Hectares</u>	<u>Units</u>	<u>Hectares</u>
Single family units	314	15.46	-	-
Semi-detached units	-	-	564	15.19
Commercial	-	0.24	-	0.24
Park and Buffer	-	1.80	-	2.07
Roads 2,730 m.	-	<u>6.16</u>	-	<u>6.16</u>
Total	314	23.66	564	23.66



1A



1B

1A

1B

CASE STUDY 1 **Residential Subdivision**



Marshall Macdon Monaghan Limited

Legend

- Semi-Detached

Figure

4.1

WORKSHEET NO. 1
RESIDENTIAL ENERGY CONSUMPTION

NO. 11A

1 Type Source	2 Plan Data		3 Energy Coefficients (Btu/ft ² /year)						4 Total of Coeffs. (Btu/ft ² /year)	5 Annual Energy (Btu)
	Number of Units	Area Floor Space (sq ft)	Space Heating	Water Heating	Space Cooling	Water Heating	Lighting and Appliances			
SP15										
SP8										
SP14	100	100	150,400	3600	24,100	2,000	24,100	21,410		
SP15	214	103	146,900	3600	24,100	2,000	24,100	43,142		
SP										
SP1										
ALR										
ALR										
OTHER										
Total Units	314	31								

SP15 - Single Family 1-2-Bedroom
SP8 - Single Family Regular
SP14 - Single Family Split Level
SP15 - Single Family Split Level
SP - Semi-Attached
ALR - Low Rise
ALR - Apartments Low Rise
ALR - Apartments High Rise

30 Total Annual Residential Energy Consumption =
(Sum of Items in Column 5)

64,552

Enter in Column 3 of Worksheet No. 2

32 Residential Energy Consumption Indicator =
30 ÷ 31

206

Enter in Column 6 of Worksheet No. 2

WORKSHEET NO. 1
RESIDENTIAL ENERGY CONSUMPTION

NO. 11B

1 Type Source	2 Plan Data		3 Energy Coefficients (Btu/ft ² /year)						4 Total of Coeffs. (Btu/ft ² /year)	5 Annual Energy (Btu)
	Number of Units	Area Floor Space (sq ft)	Space Heating	Water Heating	Space Cooling	Water Heating	Lighting and Appliances			
SP15										
SP8										
SP14										
SP15										
SP	564	103	132,400	3600	25,400	2,000	25,400	18,670	103,230	
OTHER										
ALR										
ALR										
OTHER										
Total Units	564	31								

SP15 - Single Family 1-2-Bedroom
SP8 - Single Family Regular
SP14 - Single Family Split Level
SP15 - Single Family Split Level
SP - Semi-Attached
ALR - Low Rise
ALR - Apartments Low Rise
ALR - Apartments High Rise

30 Total Annual Residential Energy Consumption =
(Sum of Items in Column 5)

105,230

Enter in Column 3 of Worksheet No. 2

32 Residential Energy Consumption Indicator =
30 ÷ 31

187

Enter in Column 6 of Worksheet No. 2

WORKSHEET NO. 2
COMMERCIAL AND INSTITUTIONAL ENERGY CONSUMPTION

NO. 11A

1 Type Source	2 Area Floor Space (sq ft)	3 Energy Coefficients (Btu/ft ² /year)						4 Total of Coeffs. (Btu/ft ² /year)	5 Annual Energy (Btu)
		Space Heating	Water Heating	Space Cooling	Water Heating	Space Cooling	Water Heating		
Office									
Medical	360							1000	360
General	360							1000	360
Retail									
Strip	600							1900	1140
Food	120							3600	432
Institutional									
Total Area (sq ft)	1440								

30 Commercial and Institutional Energy Consumption (Btu/year) =
(Sum of Items in column 5)

2292

Enter in Column 3 of Worksheet No. 2

32 Commercial Institutional Energy Consumption Indicator =
30 ÷ 31

16

Enter in Column 6 of Worksheet No. 2

WORKSHEET NO. 2
COMMERCIAL AND INSTITUTIONAL ENERGY CONSUMPTION

NO. 11B

1 Type Source	2 Area Floor Space (sq ft)	3 Energy Coefficients (Btu/ft ² /year)						4 Total of Coeffs. (Btu/ft ² /year)	5 Annual Energy (Btu)
		Space Heating	Water Heating	Space Cooling	Water Heating	Space Cooling	Water Heating		
Office									
Medical	360							1000	360
General	360							1000	360
Retail									
Strip	600							1900	1140
Food	120							3600	432
Institutional									
Total Area (sq ft)	1440								

30 Commercial and Institutional Energy Consumption (Btu/year) =
(Sum of Items in column 5)

2292

Enter in Column 3 of Worksheet No. 2

32 Commercial Institutional Energy Consumption Indicator =
30 ÷ 31

16

Enter in Column 6 of Worksheet No. 2

WORKSHEET NO. 4
TRANSPORTATION ENERGY CONSUMPTION

NO. 11A

A. Trip Productions

Shelling Unit Type	1	2	3	4	5
Source	No. of Units	Trips/Unit	Annual Trips	Persons/8.0	Total Persons
	Year	Tab. E1	1 x 2	Tab. E4	1 x 4

Single Family Detached	314	3588	1,124,632	3.5	1099
Single Family Attached					
Low - Rise Apartment					
High Rise Apartment					

6 Total Annual Trip Productions = 1,124,632 7 Population = 1099

B. Trip Attractions

Land Use Activity (Excluding Local Uses)	8	9	10	11
Source	Floor Space (sq' or Employees)	Average Trips Per Employee or Unit Area Trips/sq' Floor	Annual Trips	Persons/8.0
	Year	Tables E2 & E3	9 x 10	9 x 11

1			
2			
3			
4			
5			
6			
7			
8			

12 Total Annual Trip Attractions = D

WORKSHEET NO. 4
TRANSPORTATION ENERGY CONSUMPTION

NO. 11B

A. Trip Productions

Shelling Unit Type	1	2	3	4	5
Source	No. of Units	Trips/Unit	Annual Trips	Persons/8.0	Total Persons
	Year	Tab. E1	1 x 2	Tab. E4	1 x 4

Single Family Detached	544	2912	1,642,368	3.5	1974
Single Family Attached					
Low - Rise Apartment					
High Rise Apartment					

6 Total Annual Trip Productions = 1,642,368 7 Population = 1974

B. Trip Attractions

Land Use Activity (Excluding Local Uses)	8	9	10	11
Source	Floor Space (sq' or Employees)	Average Trips Per Employee or Unit Area Trips/sq' Floor	Annual Trips	Persons/8.0
	Year	Tables E2 & E3	9 x 10	9 x 11

1			
2			
3			
4			
5			
6			
7			
8			

12 Total Annual Trip Attractions = D

WORKSHEET NO. 4 CONT
TRANSPORTATION ENERGY CONSUMPTION

NO. 11A

C. Internal and Total Trips

33	Regional Population	Source	24,000
34	Internal Person Trips	(32 x 7) - 13	0
35	Total Person Trips	6 x 12 - 14	1,124,632

D. Passenger - Kilometres of Travel

36	Average Trip Length (KM)	Fig. E1 and Table E5	3.0
37	Total Person - Kilometres	35 x 36	3,379,896
38	Average # of Trips by Transit	Table E10	0.29
39	Total Transit Passenger - KM	37 x 38	98,017
40	Total Automobile Person - KM	37 - 39	3,281,879

E. Energy Consumption

41	Energy Intensity (MJ/Person - KM)	Table E7	1.00
42	Transit Energy Consumption (MJ/year)	39 x 41	98,017
43	Average Automobile Occupancy	Table E8	1.35
44	Average Auto Energy Consumption (MJ/Person - KM)	Table E9	6.4
45	Automobile Energy Consumption (MJ/year)	40 x 44 x 43	15,558,537

46 Total Annual Transportation Energy (MJ/year) (42 + 45) = 15,657

Enter to Column 3 of Worksheet No. 7

F. Energy Consumption Indicator

47	Total Residential Gross Floor Area (sq')	Sum of Column 2 x 3 in Worksheet No. 1	32,842
48	Total Inst./Com./Industrial GFA (sq')	Sum of Column 9	0
49	Total Gross Floor Area (sq')	47 + 48	32,842
50	Transportation Energy Consumption Indicator (MJ/sq' year)	46 x 49	0.48

Enter to Column 6 of Worksheet No. 7

WORKSHEET NO. 4 CONT
TRANSPORTATION ENERGY CONSUMPTION

NO. 11B

C. Internal and Total Trips

33	Regional Population	Source	24,000
34	Internal Person Trips	(32 x 7) - 13	0
35	Total Person Trips	6 x 12 - 14	1,642,368

D. Passenger - Kilometres of Travel

36	Average Trip Length (KM)	Fig. E1 and Table E5	3.0
37	Total Person - Kilometres	35 x 36	4,927,104
38	Average # of Trips by Transit	Table E10	0.29
39	Total Transit Passenger - KM	37 x 38	142,886
40	Total Automobile Person - KM	37 - 39	4,784,218

E. Energy Consumption

41	Energy Intensity (MJ/Person - KM)	Table E7	1.0
42	Transit Energy Consumption (MJ/year)	39 x 41	142,886
43	Average Automobile Occupancy	Table E8	1.35
44	Average Auto Energy Consumption (MJ/Person - KM)	Table E9	6.4
45	Automobile Energy Consumption (MJ/year)	40 x 44 x 43	22,689,737

46 Total Annual Transportation Energy (MJ/year) (42 + 45) = 22,832

Enter to Column 3 of Worksheet No. 7

F. Energy Consumption Indicator

47	Total Residential Gross Floor Area (sq')	Sum of Column 2 x 3 in Worksheet No. 1	58,092
48	Total Inst./Com./Industrial GFA (sq')	Sum of Column 9	0
49	Total Gross Floor Area (sq')	47 + 48	58,092
50	Transportation Energy Consumption Indicator (MJ/sq' year)	46 x 49	0.39

Enter to Column 6 of Worksheet No. 7

NO. ☐ LA

1	2	3	4	5	6
Land Use Type	Area Building Area of (acre)	Energy per sq ft (Btu/sq ft)	Energy Use Type (Btu)	Project Life Years	Annual Energy Use/year
		Table F1	Btu	Table F2	A = B
Construction of Buildings					
Residential Single Family	32,842	0-1	244,020	50	5320
Residential Two-Four Family					
Residential Over 4-unit					
Commercial Office	720	10-9	13,608	50	272
Commercial Retail	720	10-9	7848	30	262
Manufacturing					
Warehouses					
Industrial					
Other					
Total Green Building Area	34,282				5854
Total Annual Building Construct or Energy (Btu/year)					5854

Major Service Types	Length of Service (ft.) (Row)	Energy Use Type (ft.) ² Table F3	Energy Use Type (ft.) ² Table F3	Project Life Years Table F2	Annual Energy (kWh/year) Table F3
Boath	2730	30	8190	25	320
Water	2730				
Sanitary Sewers	2730				
On-site Piping	2730				
Grassland Irrigation	0				
Stormwater Management	2730				
Landscaping	2730				
Off-Farm Services	2730	564	15397	100	154
Total Annual Service Construction Energy (kWh/year)					482
35 Total Annual Construction Energy Consumption (7 + 34) = 3888 kWh/year					63
Enter in Column 3 of Worksheet No. 7					
36 Construction Energy Consumption Indicator (35 + Total Gross Building Area) kWh/year					0002
Enter in Column 8 of Worksheet No. 7					

NO. 118

1	2	3	4	5	6
Load Use Type	Green Building Env. of (Year)	Energy per sq ft (Btu/ft ²)	Energy per year (Btu)	Project 1996 Years	Annual Energy kt/year
	Table F1	Btu	Table F2	4-5	
Construction of Buildings					
Residential Single Family					
Residential Two-Four Family	50932	7-2	418,742	50	8365
Residential Manufactured					
Commercial Office	720	18-9	13,608	50	272
Commercial Retail	720	10-9	7048	30	262
Government					
Hotels					
Industrial					
Other					
Total Green Building Area	59632	Total Annual Building Construction Energy (Btu, 10 ⁶)			8899
		7			8899

8	9	10	11	12	13
Major Service Type	Length of Service (Yr) (Year)	Energy (KWH)	Energy Use Type (EUI)	Project Life Years	Annual Energy (MJ/year)
		Table F3	Table 5	Table F2	11-12

Construction of Services

Roofs	2730	3-0	B130	25	328
Water	2730	1			
Sanitary Sewers	2730				
Stormwater Piping	2730				
Stormwater Discharging	0				
Stormwater Wastewater	2730				
Sanitary Sewers	2730				
All Fixed Services	2730	564	15,397	100	154

Total Annual Service Construction Energy, MJ	482	482
--	-----	-----

Enter in Column 3 of Worksheet No. 7

34	Total Annual Construction Energy Consumption (7 + 36) = 3886	61/year	9.4
----	--	---------	-----

Enter in Column 3 of Worksheet No. 7

35	Construction Energy Consumption Indicator (15 + Total Gross Building Area)	610/year	.0002
----	--	----------	-------

Enter in Column 3 of Worksheet No. 7

NO. 1A

1	2	3	4
Load Use Type	Number of Units or Area	Service Energy Factor	Annual Energy Consumption
Source	Worksheets 1.2. and 3	Table B5	Ba3
Residential - Single Family	314 units	2000 MJ/unit	628,000
Residential - Multi-Family			
Residential - Apartments			
Commercial - Office	720 m ²	110 MJ/m ²	7,920
Commercial - Retail	720 m ²	520 MJ/m ²	37,440
Schools/Col			
Hospital			
Industrial - Light			
Industrial - Heavy			
Mfg			

Sub Total (Sum of Column 4)	673360
--------------------------------	--------

6. Energy Consumption Contingency Factor (See Section 3.6.2)	1.15
---	------

9	Total Annual Energy Consumption See Instructions on Revisions, Table 1-1000	GJ/Year	774
---	--	---------	-----

Order to Column 3 of Worksheet No. 7

Operation of Service Entry Indicator	0-023
--------------------------------------	-------

Refer to Figure 6 of Worksheet No. 7

NO. 118

1	2	3	4
Load Use Type	Number of units or Area	Service Energy Factor	Annual Energy Consumption
Source	Months 1, 2, and 3	Table 1B	It3
Residential - Single Family	564 units	1500 MJ/unit	846,000
Residential - Two-Four Family	720 m ²	110 MJ/m ²	79,200
Residential - Apartment	720 m ²	520 MJ/m ²	374,400
Commercial - Office			
Commercial - Retail			
School/College			
Hospital			
Industrial - Light			
Industrial - Heavy			
Other			

Sub Total (Sum of Column 4)	881,360
--------------------------------	---------

6	Energy Consumption Contingency Factor (See Section 3.6.2)	1.15
---	--	------

7	Total Annual Energy Consumption for Operation of Services (Self)--2000	61/Year	1025
---	---	---------	------

8 Operation of Services Energy Indicator (7 = Sum of Column 2 Worksheet No. 9) \$/kWh/year	0.017
---	-------

Enter in column 6 of Worksheet No. 1

WORKSHEET NO. 7
ENERGY CONSUMPTION - SUMMARY

NO. 11A

Line No.	Category	Worksheet Source	Total Annual Energy Consumption (GJ/year)	Distribution & (Total of 100%)	Worksheet Source (Indicators)	Energy Consumption Indicators
----------	----------	------------------	---	--------------------------------	-------------------------------	-------------------------------

7	Residential	No. 1 Line 10	64,552	77.5	No. 1 Line 12	206 GJ/m ² /year
8	Commercial and Institutional	No. 2 Line 13	2,292	2.8	No. 2 Line 14	1.6 GJ/m ² /year
9	Industrial	No. 3 Line 8	0	0	No. 3 Line 9	0 GJ/m ² /year
10	Transportation	No. 4 Line 20	15,657	19.0	No. 4 Line 21	0.48 GJ/m ² /year
11	Construction	No. 5 Line 25	6	-	No. 5 Line 26	0.002 GJ/m ² /year
12	Operation of Services	No. 6 Line 7	774	0.9	No. 6 Line 8	0.023 GJ/m ² /year

Total Annual Energy Consumption
1. of Project Development
(Sum of Column 3)

83,281
GJ/year

WORKSHEET NO. 7
ENERGY CONSUMPTION - SUMMARY

NO. 11B

Line No.	Category	Worksheet Source	Total Annual Energy Consumption (GJ/year)	Distribution & (Total of 100%)	Worksheet Source (Indicators)	Energy Consumption Indicators
----------	----------	------------------	---	--------------------------------	-------------------------------	-------------------------------

7	Residential	No. 1 Line 10	105,239	80.1	No. 1 Line 12	187 GJ/m ² /year
8	Commercial and Institutional	No. 2 Line 13	2,292	1.7	No. 2 Line 14	1.6 GJ/m ² /year
9	Industrial	No. 3 Line 8	0	0	No. 3 Line 9	0 GJ/m ² /year
10	Transportation	No. 4 Line 20	22,824	17.4	No. 4 Line 21	0.39 GJ/m ² /year
11	Construction	No. 5 Line 25	9	-	No. 5 Line 26	0.002 GJ/m ² /year
12	Operation of Services	No. 6 Line 7	1025	0.8	No. 6 Line 8	0.017 GJ/m ² /year

Total Annual Energy Consumption
of Project Development
(Sum of Column 3)

131,449
GJ/year

4.2.2 Calculation of Energy Consumption

The following sections describe the inputs required to complete Worksheets 1 through 7 for Alternatives 1A and 1B.

Worksheet No. 1 - Residential

The base residential dwelling types in Section A of the Catalogue are used for the calculations. It is assumed that the unit mix in Alternative 1A includes 100 split level units and 214 two storey units. These units in both Alternative 1A and 1B have total floor areas which are similar to the base values shown in Table A5 of the Catalogue. The space heating coefficient for these units in Orillia can be obtained directly from Table A1.

Worksheet No. 2 - Commercial and Institutional Uses

The commercial site is 0.24 ha (2,400 m²) in size. As more detailed information about the uses on this site was not available Orillia's Zoning By-law 1973-100 was consulted to determine that coverage in a 'C2' Neighbourhood Commercial zone is 60%. This coverage would permit $0.60 \times 2400 = 1440$ m² gross building area and it is assumed that this building will be two storeys, with offices on the second floor.

Commercial Summary:

Retail:	Food	120 m ²
	Strip	600 m ²
Office:	Medical offices	360 m ² (assumed at 50% of all offices)
	Other offices	<u>360 m²</u>
		1,440 m ²

These figures are entered in Column 2 and Table C1 consulted for the appropriate Energy Coefficients.

Worksheet No. 4 - Transportation

It is assumed that the commercial uses proposed are local in nature and the majority of trips attracted to these uses will be from within the subdivision. They are, therefore, not included in the Trip Attraction section of the worksheet. The average trip length of 3 km is obtained from the general data presented in Table E5 of the Catalogue.

Worksheet No. 5 - Construction

The gross floor areas for each residential dwelling type are obtained from column 3 of Worksheet No.1 and multiplied by the number of units for each type to obtain the total gross floor area. The gross floor areas for commercial uses are obtained from column 2 of Worksheet No. 2. It is assumed that the length of a road (obtained from the schedule of land use on the draft plan) can be used as a guide for the length of services. The type of services to be built was taken from either the additional information presented on the draft plan of subdivision or from the subdivision application form.

Worksheet No. 6 - Operation of Services

The information for Column 2 on this worksheet was taken from other worksheets.

Worksheet No. 7 - Summary

From the results of the six basic worksheets the total annual energy consumption for the construction and operation of both Alternatives and the calculated indicators are presented.

4.2.3 Conclusions - Case Study One

A comparison of Worksheet No.7 for alternatives A and B reveal a similar distribution of energy consumption. Although more energy is used for residential purposes in Alternative 1B, the indicators show a drop in the per unit consumption of 9.2%, mainly due to a smaller floor area and lower space heating costs. It can also be seen from a comparison of the Transportation Indicators that development at higher densities reduces the energy consumed on a per m² basis. In this example a drop of 21% is obtained by using semi-detached rather than single detached units indicating a substantial per unit benefit.

4.3

Case Study Two - Residential Secondary Plan

This case study is a comparison of two alternative development concepts for a secondary planning area of approximately 112 ha (275 acres). Alternative 2A contains a lower density mix of large houses and the associated schools, parks and local commercial facilities. A light industrial area is proposed adjacent to the expressway forming the northern boundary of the project. Alternative 2B contains a higher density mix of residential units and an additional industrial area along the southern boundary of the project. It is also assumed that the residential units will be upgraded to a higher standard of energy conservation in the second alternative.

For the purposes of this case study, it is presumed that the secondary planning area is located in Hamilton, and that some detailed local data is available to be used in the worksheets. The case study will be carried out using the information obtained from alternative draft plans of subdivision for the entire area, but most information required for this level of analysis could be found in the secondary plans prepared for many projects of this size.

The property is located at the intersection of a major arterial road and a controlled access highway. The site consists of vacant agricultural land with no development constraints and a small subdivision on private services, which is to be redeveloped. The open space network in each alternative contains two utility corridors and a woodlot that the municipality wishes to preserve. A noise analysis recommended that industrial uses be placed next to the expressway as a buffer zone.

4.3.1

Land Use

Alternative 2A consists of 1,099 residential units, two schools, four parks, one church/day-care centre, two commercial sites, and 12 hectares (30 acres) of industrial development. Alternative

2B contains 2,029 housing units, two schools, 5 parks, a church/day-care centre, 2 commercial sites and 18 hectares of industrial land. The general distribution of land uses is shown in Figures 4.2 and 4.3. Land use information available to the user is listed below.

<u>Land Use</u>	<u>Alternative 2A</u>		<u>Alternative 2B</u>	
	<u>Units</u>	<u>Hectares</u>	<u>Units</u>	<u>Hectares</u>
Single Family Units	687	37.55	499	27.16
Semi-detached Units	364	14.19	286	10.72
Street Townhousing	48	1.17	36	0.97
Block Townhousing	-	-	109	2.91
Low Rise Apartments	-	-	392	3.92
High Rise Apartments	-	-	743	5.95
Schools	-	4.05	-	2.02
Parks and Walkways	-	8.06	-	8.24
Open Space & Buffer Zones	-	7.82	-	9.07
Commercial	-	1.50	-	1.62
Church/Day-care	-	0.61	-	0.61
Industrial	-	12.11	-	17.64
Roads and Widenings (11,300m -A, 8,100m B)		25.10		21.33
Total	1,099	112.16	2,029	112.16



CASE STUDY 2A Secondary Plan - City



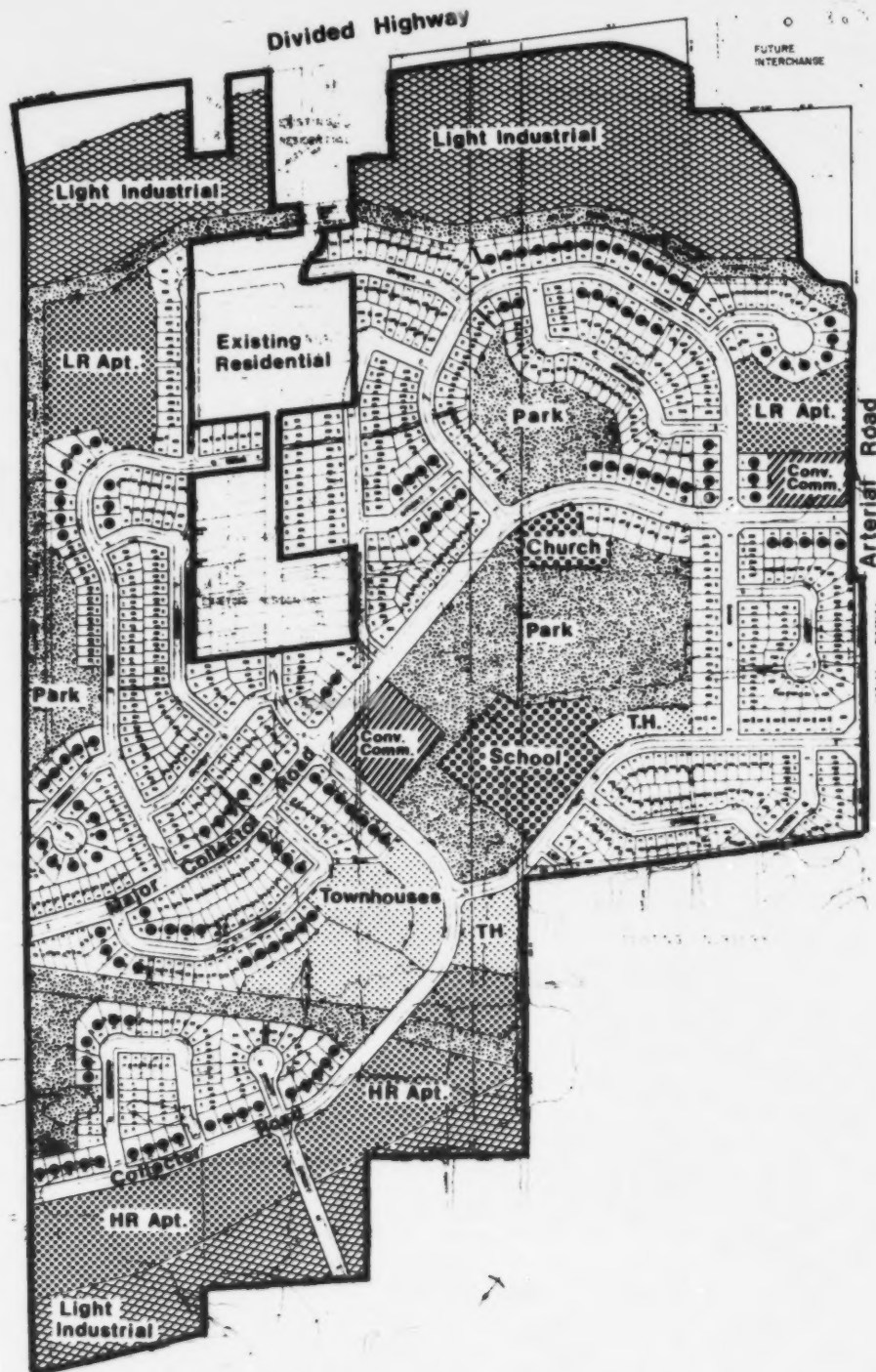
Marshall Macdon Monaghan Limited

Legend

- Semi-Detached
- TH Townhouses

Figure

4.2



CASE STUDY 2B

Secondary Plan - City



Marshall Macklin Monaghan Limited

Legend

- Semi-Detached
- TH Townhouses
- LR Apt. Low Rise Apartments
- HR Apt. High Rise Apartments

Figure

4.3

NO. 215[illegible]

July			.	.	.		
AUG			.	.	.		
SEPTE			.	.	.		
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WEEK END	1099	\$1					

- SFL5 - Single Family L-Shaped
- SFL6 - Single Family Gabled
- SFL4 - Single Family Split Level
- SFL7 - Single Family Two Story
- SD - Semi-Detached
- RM - Row House
- ALD - Apartments Low Rise
- ADR - Apartments High Rise

20	Total Annual Residential Energy Consumption = (Sum of Rows 16 to 20) (Btu/year)	212,300
----	--	---------

Enter in Column 3 of Worksheet No. 7

134

Enter in Column G of Worksheet No. 1

NO. ☐ 15

Self Type	Plan Size		Storage Specifications (GB/disk/yr)				Total of Storage Config's Chosen (GB/disk/yr)	3 Month Storage
	Number of Servers	Number of Planes (w/yr)	Disk Size	Disk Lag	Disk Rotating	Lightning and Cloud Access		
Storage	Star	Star	100GB	100GB	100GB	100GB	400GB x 4 = 1,600	2000 x 100GB = 200,000
SP/L	29	164	13,500	24,000	24,100	21,000	84,600	18,684
SP/S	100	97	21,500	24,000	24,100	21,000	84,600	13,640
SP/L	100	108	22,500	24,000	24,100	21,000	84,600	14,600
SP/S	2,000	103	24,100	24,000	24,100	21,000	84,600	57,360
SP	2,046	103	76,300	77,000	25,400	21,000	134,000	97,446
SP	145	99	64,000	77,000	17,500	21,000	119,000	15,979
OTHER				.	.	.		
				.	.	.		
				.	.	.		
				.	.	.		

2.3	392	100	59,200	4,200	12,400	17,000	33,500	36,150
200	743	100	45,600	2,500	12,400	17,000	77,500	57,500
0103			.	.	.	.		
			.	.	.	.		
			.	.	.	.		
			.	.	.	.		
			.	.	.	.		
2001 0010	2065	13						

SPS - Single Family L-Shaped
 SPB - Single Family Regular
 SPCL - Single Family Split Level
 SPVS - Single Family Van Storey
 SS - Semi-Detached
 SS - Row House
 ASL - Apartments Low Rise
 ASH - Apartments High Rise

28	Total Annual Residential Energy Consumption = (sum of items 1a to 4 above) (Btu/year)	22,324
----	--	--------

Enter in Column 3 of Worksheet No. 2

Residential Energy Consumption Indicator = 108
 10 = 11 Btu/unit/year

Page to Column 6 of Worksheet No. 7

2A

TABLE A5
ADJUSTED SPACE HEATING LOADS

Calculation	Unit Type	L-Shaped One Storey	Regular One Storey	Split Level	Two Storey	Semi Detached	Row House
Floor Area Adjustment § (Table A3)		+ 20	+ 20	+ 20	+ 20	+ 20	+ 20
Net Heat Load kJ/°C-hr (Table A3)		1435	315	1009	377	845	680
Insulation Adjustments kJ/°C-hr (Table A4)							
Roof		"	"	"	"	"	"
Exterior Wall		"	"	"	"	"	"
Foundation Wall		"	"	"	"	"	"
Crack Gaps		"	"	"	"	"	"
Door		"	"	"	"	"	"
Sub Total (Sum 5-7) or All Factors (Table A4)		0	0	0	0	0	0
Ventilation Adjustment (Table A5)		0	0	0	0	0	0
Adjusted Net Heat Load 2 x (8 or 9) + 10 kJ/°C-hr		1435	315	1009	377	845	680
Daily Heat Load 11 = 24 hr/day		34,440	22,052	24,216	12,008	20,280	16,320
Heating Degree Days (Table A1)		3710	3710	3710	3710	3710	3710
Furnace Efficiency (Table B4)		0.6	0.6	0.6	0.6	0.6	0.6
Annual Heat Load Factor 12 = 13 + 14 + 1000 kJ/Year		212,354	84,231	107,761	34,083	85,398	60,960

2B

TABLE A5
ADJUSTED SPACE HEATING LOADS

Calculation	Unit Type	L-Shaped One Story	Regular One Story	Split Level	Two Story	Semi-Detached	Row House
1. Floor Area Adjustment (Table A3)		Basic	Basic	Basic	Basic	Basic	Basic
2. Net Heat Load k.J./°C-Hr (Table A3)		1233	775	845	788	719	594
Insulation Adjustments k.J./°C-Hr (Table A4)							
3. Roof		"	"	"	"	"	"
4. Exterior Wall		"	"	"	"	"	"
5. Foundation Wall		"	"	"	"	"	"
6. Triple Glass		"	"	"	"	"	"
7. Door		"	"	"	"	"	"
8. Sub Total (Sum 3-7) or							
9. All Factors (Table A4)		-347	-223	-244	-221	-201	-163
10. Ventilation Adjustment (Table A3)		0	0	0	0	0	0
11. Adjusted Net Heat Load $2 \times (8 \text{ or } 9) \times 10$ k.J./°C-Hr		886	552	621	567	518	431
12. Daily Heat Load 11×24 hr/day		21,264	13,248	14,904	13,608	12,432	10,344
Heating Degree Days (Table A1)		3710	3710	3710	3710	3710	3710
14. Furnace Efficiency (Table B4)		0.6	0.6	0.6	0.6	0.6	0.6
15. Annual Heat Load Factor $12 \times 10 \times 10 \times 1000$ MJ/Year		13,482	8,197	9,154	8,403	76,871	63,262

NO. ☐ 215

WORKSHEET NO. 2 NO. 21
COMMERCIAL AND INSTITUTIONAL ENERGY CONSUMPTION

[illegible]NO ☒ 2A[illegible]

NO 28

1 Industry (Category)	2 Area	3 Sub-Industry (Category)	4 Sub-Industry (Category)	5 Sub-Industry (Category)	6 Sub-Industry (Category)	7 Sub-Industry (Category)	8 Sub-Industry (Category)	9 Sub-Industry (Category)	10 Sub-Industry (Category)
Table 101	Table 102	Table 103	Table 104	Table 105	Table 106	Table 107	Table 108	Table 109	Table 110
Table 111	Table 112	Table 113	Table 114	Table 115	Table 116	Table 117	Table 118	Table 119	Table 120
Table 121	Table 122	Table 123	Table 124	Table 125	Table 126	Table 127	Table 128	Table 129	Table 130
Table 131	Table 132	Table 133	Table 134	Table 135	Table 136	Table 137	Table 138	Table 139	Table 140
Table 141	Table 142	Table 143	Table 144	Table 145	Table 146	Table 147	Table 148	Table 149	Table 150
Table 151	Table 152	Table 153	Table 154	Table 155	Table 156	Table 157	Table 158	Table 159	Table 160
Table 161	Table 162	Table 163	Table 164	Table 165	Table 166	Table 167	Table 168	Table 169	Table 170
Table 171	Table 172	Table 173	Table 174	Table 175	Table 176	Table 177	Table 178	Table 179	Table 180
Table 181	Table 182	Table 183	Table 184	Table 185	Table 186	Table 187	Table 188	Table 189	Table 190
Table 191	Table 192	Table 193	Table 194	Table 195	Table 196	Table 197	Table 198	Table 199	Table 200
Table 201	Table 202	Table 203	Table 204	Table 205	Table 206	Table 207	Table 208	Table 209	Table 210
Table 211	Table 212	Table 213	Table 214	Table 215	Table 216	Table 217	Table 218	Table 219	Table 220
Table 221	Table 222	Table 223	Table 224	Table 225	Table 226	Table 227	Table 228	Table 229	Table 230
Table 231	Table 232	Table 233	Table 234	Table 235	Table 236	Table 237	Table 238	Table 239	Table 240
Table 241	Table 242	Table 243	Table 244	Table 245	Table 246	Table 247	Table 248	Table 249	Table 250
Table 251	Table 252	Table 253	Table 254	Table 255	Table 256	Table 257	Table 258	Table 259	Table 260
Table 261	Table 262	Table 263	Table 264	Table 265	Table 266	Table 267	Table 268	Table 269	Table 270
Table 271	Table 272	Table 273	Table 274	Table 275	Table 276	Table 277	Table 278	Table 279	Table 280
Table 281	Table 282	Table 283	Table 284	Table 285	Table 286	Table 287	Table 288	Table 289	Table 290
Table 291	Table 292	Table 293	Table 294	Table 295	Table 296	Table 297	Table 298	Table 299	Table 300
Table 301	Table 302	Table 303	Table 304	Table 305	Table 306	Table 307	Table 308	Table 309	Table 310
Table 311	Table 312	Table 313	Table 314	Table 315	Table 316	Table 317	Table 318	Table 319	Table 320
Table 321	Table 322	Table 323	Table 324	Table 325	Table 326	Table 327	Table 328	Table 329	Table 330
Table 331	Table 332	Table 333	Table 334	Table 335	Table 336	Table 337	Table 338	Table 339	Table 340
Table 341	Table 342	Table 343	Table 344	Table 345	Table 346	Table 347	Table 348	Table 349	Table 350
Table 351	Table 352	Table 353	Table 354	Table 355	Table 356	Table 357	Table 358	Table 359	Table 360
Table 361	Table 362	Table 363	Table 364	Table 365	Table 366	Table 367	Table 368	Table 369	Table 370
Table 371	Table 372	Table 373	Table 374	Table 375	Table 376	Table 377	Table 378	Table 379	Table 380
Table 381	Table 382	Table 383	Table 384	Table 385	Table 386	Table 387	Table 388	Table 389	Table 390
Table 391	Table 392	Table 393	Table 394	Table 395	Table 396	Table 397	Table 398	Table 399	Table 400
Table 401	Table 402	Table 403	Table 404	Table 405	Table 406	Table 407	Table 408	Table 409	Table 410
Table 411	Table 412	Table 413	Table 414	Table 415	Table 416	Table 417	Table 418	Table 419	Table 420
Table 421	Table 422	Table 423	Table 424	Table 425	Table 426	Table 427	Table 428	Table 429	Table 430
Table 431	Table 432	Table 433	Table 434	Table 435					

WORKSHEET NO. 4
TRANSPORTATION ENERGY CONSUMPTION

NO. 2A

A. Trip Productions

Building Unit Type	3	4	5	6	7
Source	Use	Tab. E1	Tab. E2	Tab. E4	Tab. E6
Single Family Detached	687	3500	2,464,964	3-5	2405
Single Family Attached	412	2512	1,199,744	3-5	1442
Low - Rise Apartment					
High Rise Apartment					

8 Total Annual Trip Productions = 3,664,700 9 Population = 3847

B. Trip Attractions

Land Use Activity (Excluding Local Uses)	8	9	10	11
Source	Use	Floor Space (sq ft) or Employees	Average Trips Per Employee or Unit Area Trips/sq/yr	Annual Trips Tab. E2 & E3
1 Light Industrial		72,660 sq ft	17	1,235,220
2 School		500 students	260 trips/student	130,000
3				
4				
5				
6				
7				
8				

12 Total Annual Trip Attractions = 1,365,220

WORKSHEET NO. 4
TRANSPORTATION ENERGY CONSUMPTION

NO. 2B

A. Trip Productions

Building Unit Type	3	4	5	6	7
Source	Use	Tab. E1	Tab. E2	Tab. E4	Tab. E6
Single Family Detached	499	3500	1,730,412	3-5	1747
Single Family Attached	431	2512	1,255,072	3-5	1509
Low - Rise Apartment	392	1664	652,288	2-5	980
High Rise Apartment	743	1144	849,992	2-5	1050

8 Total Annual Trip Productions = 4,547,764 9 Population = 6094

B. Trip Attractions

Land Use Activity (Excluding Local Uses)	8	9	10	11
Source	Use	Floor Space (sq ft) or Employees	Average Trips Per Employee or Unit Area Trips/sq/yr	Annual Trips Tab. E2 & E3
1 Light Industrial		105,840	17	1,799,280
2				
3				
4				
5				
6				
7				
8				

12 Total Annual Trip Attractions = 1,799,280

WORKSHEET NO. 4 CONT
TRANSPORTATION ENERGY CONSUMPTION

NO. 2A

C. Internal and Total Trips

Source	33	34	35
Regional Population	Use	410,045	
Internal Person Trips	(32 x 7) = 33	12,808	
Total Person Trips	8 x 32 = 31	5,017,112	

D. Passenger - Kilometres of Travel

Fig. E1 and Table E3	36	37	38	39	40
Average Trip Length (km)	Use	8.4			
Total Person - Kilometres	35 x 36	42,143,741			
Average S of Trips by Transit	Tab. E3	0.12			
Total Transit Passenger - km	37 x 38	5,057,249			
Total Automobile Person - km	37 x 39	37,086,492			

E. Energy Consumption

Table E7	41	42	43	44	45
Energy Intensity (MJ/Pass. - km)	Use	1.00			
Transit Energy Consumption (MJ/year)	39 x 41	5,057,249			
Average Automobile Occupancy	Table E8	1.4			
Average Auto Energy Consumption (MJ/veh. - km)	Table E9	6.4			
Automobile Energy Consumption (MJ/year)	39 x 42 x 44	16,538,249			

46 Total Annual Transportation Energy (MJ/year) (22 x 25) = 1000 174,595

Enter to Column 2 of Worksheet No. 7

F. Energy Consumption Indicator

Sum of Column 2 x 5 in Worksheet No. 7	47	48	49	50
Total Residential Gross Floor Area (sq ft)	Use	14,987		
Total Inst. Area / Industrial (sq ft)	Sum of Column 5	76,160		
Total Gross Floor Area (sq ft)	37 x 48	216,147		
Transportation Energy Consumption Indicator (MJ/sq ft/year)	46 x 49	0.61		

Enter to Column 6 of Worksheet No. 7

WORKSHEET NO. 4 CONT
TRANSPORTATION ENERGY CONSUMPTION

NO. 2B

C. Internal and Total Trips

Source	33	34	35
Regional Population	Use	410,045	
Internal Person Trips	(32 x 7) = 33	26,741	
Total Person Trips	8 x 32 = 34	6,380,363	

D. Passenger - Kilometres of Travel

Fig. E1 and Table E7	36	37	38	39	40
Average Trip Length (km)	Use	8.4			
Total Person - Kilometres	35 x 36	53,030,545			
Average S of Trips by Transit	Table E3	0.12			
Total Transit Passenger - km	37 x 38	6,370,665			
Total Automobile Person - km	37 x 39	46,719,680			

E. Energy Consumption

Table E7	41	42	43	44	45
Energy Intensity (MJ/Pass. - km)	Use	1.00			
Transit Energy Consumption (MJ/year)	39 x 41	6,370,665			
Average Automobile Occupancy	Table E8	1.4			
Average Auto Energy Consumption (MJ/veh. - km)	Table E9	6.4			
Automobile Energy Consumption (MJ/year)	39 x 42 x 44	23,575,678			

46 Total Annual Transportation Energy (MJ/year) (22 x 25) = 1000 219,946

Enter to Column 2 of Worksheet No. 7

F. Energy Consumption Indicator

Sum of Column 2 x 5 in Worksheet No. 7	47	48	49	50
Total Residential Gross Floor Area (sq ft)	Use	214,649		
Total Inst. Area / Industrial (sq ft)	Sum of Column 5	105,840		
Total Gross Floor Area (sq ft)	37 x 48	320,489		
Transportation Energy Consumption Indicator (MJ/sq ft/year)	46 x 49	0.69		

Enter to Column 6 of Worksheet No. 7

WORKSHEET NO. 5
CONSTRUCTION ENERGY CONSUMPTION

NO. 12A

1	2	3	4	5	6
Land Use Type	Gross Building Area of (Sq. ft.)	Energy per sq. ft. (Btu/yr)	Energy by Type (Btu)	Project Life Years	Annual Energy (Btu/yr)
		Table F2	Btu	Table F2	6-5
Construction of Buildings					
Residential - Single Family	91,130	8-1	739,226	50	14,765
Residential - Two-Four Family	50,848	7-2	346,104	50	7,322
Residential - Apartment					
Commercial - Office	1,500	18-9	28,350	50	567
Commercial - Retail	1,750	10-9	12,075	30	636
Educational	3,000	15-9	47,700	50	954
Hospital					
Industrial	72,440	11-2	813,932	20	40,690
Other - Church	1,000	15-9	15,300	50	318
Total Gross Building Area	221,897				
Total Annual Building Construction Energy (Btu/yr)				65,251	65,251

7	8	9	10	11	12
Major Service Types	Length of Service (Yr.)	Energy by Type (Btu/yr)	Project Life Years	Annual Energy (Btu/yr)	11-12
	Table F2	Btu	Table F2	11-12	
Construction of Services					
Boiler	11,300	3-0	33,900	25	1356
Water	11,300				
Sanitary Sewers	11,300				
Storm Sewer	11,300				
Stormwater Detention	0				
Stormwater Detention	11,300				
Sanitary Sewer	11,300				
Total Annual Service Construction Energy (Btu/yr)		564	63,732	100	637
Total Annual Construction Energy Consumption (7 + 6) - Btu/yr				1993	1993
Total Annual Construction Energy Consumption (7 + 6) - kWh/yr				67	67
Construction Energy Consumption Indicator (10 + Total Gross Building Area) kWh/yr				0.003	0.003

WORKSHEET NO. 5
CONSTRUCTION ENERGY CONSUMPTION

NO. 12B

1	2	3	4	5	6
Land Use Type	Gross Building Area of (Sq. ft.)	Energy per sq. ft. (Btu/yr)	Energy by Type (Btu)	Project Life Years	Annual Energy (Btu/yr)
		Table F2	Btu	Table F2	6-5
Construction of Buildings					
Residential - Single Family	57,326	8-1	444,422	50	9280
Residential - Two-Four Family	43,813	7-2	315,454	50	6309
Residential - Apartment					
Commercial - Office	113,500	8-5	944,750	50	19,255
Commercial - Retail	2,300	18-9	43,470	50	869
Educational	2,500	10-9	27,250	30	908
Hospital	1,500	15-9	23,050	50	477
Industrial	15,840	11-2	1,185,440	20	59,270
Other - Church	1,000	15-9	15,300	50	318
Total Gross Building Area	327,789				
Total Annual Building Construction Energy (Btu/yr)				36,734	36,734

7	8	9	10	11	12
Major Service Types	Length of Service (Yr.)	Energy by Type (Btu/yr)	Project Life Years	Annual Energy (Btu/yr)	11-12
	Table F2	Btu	Table F2	11-12	
Construction of Services					
Boiler	8400	3-0	24,300	25	972
Water	8400				
Sanitary Sewers	8400				
Storm Sewer	8400				
Stormwater Detention	0				
Stormwater Detention	8400				
Sanitary Sewer	8400				
Total Annual Service Construction Energy (Btu/yr)		564	45,684	100	457
Total Annual Construction Energy Consumption (7 + 6) - Btu/yr				1429	1429
Total Annual Construction Energy Consumption (7 + 6) - kWh/yr				98	98
Construction Energy Consumption Indicator (10 + Total Gross Building Area) kWh/yr				0.003	0.003

WORKSHEET NO. 6
OPERATION OF SERVICES ENERGY CONSUMPTION

NO. 12A

1	2	3	4
Land Use Type	Number of Units or Area	Service Energy Factor	Annual Energy Consumption
	Worksheet 3.2, and 3	Table G5	Btu
Residential - Single Family	687 units	2000 MJ/unit	1,374,000
Residential - Two-Four Family	412 units	1500 MJ/unit	618,000
Residential - Apartment			
Commercial - Office	1500 m ²	11 MJ/m ²	16,500
Commercial - Retail	1750 m ²	52 MJ/m ²	91,000
Educational	2 schools (1000 sq ft)	200,000 MJ/school	200,000
Hospital			
Industrial - Light	12.11 ha	55,000 MJ/ha	666,050
Industrial - Heavy			
Other - Church	1000 m ²	11 MJ/m ² (assuming office)	11,000

Sub Total (Sum of Column 4) 2,976,550

Energy Consumption Contingency Factor (See Section 3.4.2)	1.15
Total Annual Energy Consumption for Operation of Services (Sub 1) - kWh/yr	3423
Operation of Services Energy Indicator (7 + Sum of Column 2 Worksheet No. 5) kWh/yr	0.015

WORKSHEET NO. 6
OPERATION OF SERVICES ENERGY CONSUMPTION

NO. 12B

1	2	3	4
Land Use Type	Number of Units or Area	Service Energy Factor	Annual Energy Consumption
	Worksheet 3.2, and 3	Table G5	Btu
Residential - Single Family	433 units	2000 MJ/unit	866,000
Residential - Two-Four Family	431 units	1500 MJ/unit	646,500
Residential - Apartment	1135 units	1500 MJ/unit	1,702,500
Commercial - Office	2300 m ²	11 MJ/m ²	25,300
Commercial - Retail	2500 m ²	52 MJ/m ²	130,000
Educational	1 school (500 sq ft)	200,000 MJ/school	180,000
Hospital			
Industrial - Light	7.64 ha	55,000 MJ/ha	970,200
Industrial - Heavy			
Other - Church	1000 m ²	11 MJ/m ² (assuming office)	11,000

Sub Total (Sum of Column 4) 4,583,500

Energy Consumption Contingency Factor (See Section 3.4.2)	1.15
Total Annual Energy Consumption for Operation of Services (Sub 1) - kWh/yr	5271
Operation of Services Energy Indicator (7 + Sum of Column 2 Worksheet No. 5) kWh/yr	0.016

WORKSHEET NO.7
ENERGY CONSUMPTION - SUMMARY

NO. **B/A**

Line No.	Category	Worksheet Source	Total Annual Energy Consumption (kWh/year)	Distribution % (Total of SP)	Worksheet Source (Indicators)	Energy Conversion Indicators
----------	----------	------------------	--	------------------------------	-------------------------------	------------------------------

7	Residential	No. 3 Line 30	212,509	45.8	No. 3 Line 32	184 kWh/year
8	Commercial and Institutional	No. 2 Line 33	2,330	2.1	No. 2 Line 34	1.3 kWh/year
9	Industry	No. 3 Line 9	36,166	8.3	No. 3 Line 9	2586 kWh/year
10	Transportation	No. 4 Line 36	174,595	40.0	No. 4 Line 38	0.01 kWh/year
11	Construction	No. 5 Line 35	67	-	No. 5 Line 35	0.003 kWh/year
12	Electricity at Service	No. 6 Line 7	3,423	0.8	No. 6 Line 8	0.015 kWh/year

Total Annual Energy Consumption of Fed. and Government (Sum of Column 3) **436,489 kWh/year**

WORKSHEET NO.7
ENERGY CONSUMPTION - SUMMARY

NO. **B/B**

Line No.	Category	Worksheet Source	Total Annual Energy Consumption (kWh/year)	Distribution % (Total of SP)	Worksheet Source (Indicators)	Energy Conversion Indicators
----------	----------	------------------	--	------------------------------	-------------------------------	------------------------------

7	Residential	No. 3 Line 30	223,224	43.5	No. 3 Line 32	100 kWh/year
8	Commercial and Institutional	No. 2 Line 33	10,245	2.0	No. 2 Line 34	1.4 kWh/year
9	Industry	No. 3 Line 9	52,680	10.3	No. 3 Line 9	2586 kWh/year
10	Transportation	No. 4 Line 36	219,946	43.1	No. 4 Line 38	0.49 kWh/year
11	Construction	No. 5 Line 35	30	-	No. 5 Line 35	0.003 kWh/year
12	Electricity at Service	No. 6 Line 7	5,271	1.0	No. 6 Line 8	0.016 kWh/year

Total Annual Energy Consumption of Private Development (Sum of Column 3) **510,464 kWh/year**

4.3.2 Calculation of Energy Consumption

The following sections describe the inputs required to complete Worksheets 1 - 7 for both Alternatives.

Worksheet No.1 - Residential

The single family units are to be built in the following mix:

L-shaped bungalows	-	87	99
Regular bungalows	-	200	100
Split level houses	-	200	100
Two-storey houses	-	200	100
Total	-	687	499

To demonstrate the capability of the manual to consider variations in unit size the residential units in Alternative 2A will be 20% larger than the standard units shown in Table A5. The corrected space heating coefficients were calculated using Table A9 in the Catalogue. The net heat load for the 20% larger units is found in Table A6 and the number of heating degree days for Hamilton is listed in Table A1.

The single family houses in Alternative 2B were assumed to be the standard floor area in Table A5, but to be insulated to the improved levels shown in Table B1. The correct heating factors for the houses are calculated using Table A9 in Section A of the Catalogue. The base heating coefficients were modified by "the all factors" improved value from Table A7.

The remainder of Worksheet No.1 is completed in the normal manner, using the information provided in the Catalogue.

Worksheet No. 2 - Commercial and Institutional Uses

The commercial site in the centre of each plan is 1.0 hectares and is assumed to be for local commercial needs. The local zoning by-law permits approximately 30% coverage and a maximum height of two storeys. The following mix is assumed for both alternatives:

Food store	-	500 m ²
Other retail	-	1,000 m ²
Medical offices	-	750 m ²
Other offices	-	<u>750 m²</u>
		3,000 m ²

It is assumed that the second commercial site in Alternative 2A will be used for an automobile service station. It is estimated that the building will have a gross floor area of 150 m² on a 0.5 hectare lot. The second commercial site in Alternative 2B is 0.6 hectares and is assumed to contain a convenience food store, and other retail and offices uses is presented below. The zoning by-law permits local commercial development at 0.3 of lot area.

Convenience food	-	100 m ²
Other retail	-	900 m ²
Office	-	<u>800 m²</u>
Total	-	1,800 m ² @ 30% = 0.6 hectare

Two elementary schools are included in Alternative 2A and it is assumed that both will have approximately 500 students and be 1,500 m² in area. One school is assumed to be a separate school board facility which will attract pupils from a broad area. The school in Alternative 2B is assumed to be a public school for 500 students with a gross floor area of 1,500 m².

The church and day-care centre is assumed to be a multi-use structure of approximately 1,000 m² with unit energy requirements similar to those of a school.

Worksheet No. 3 - Industrial Energy Use

The secondary plans propose prestige industrial uses adjacent to the expressway for both cases and a second industrial area on the south boundary in Alternative 2B. An examination of the local zoning by-law and surrounding industrial areas indicates that the light industry category from Table D1 should be used. The number of employees is estimated using the value of 40 employees per hectare from Table D2. Thus the industrial area will generate 485 employees in Alternative 2A and 705 employees in Alternative 2B.

In addition, the Hamilton Zoning By-law 6593 permits 60% coverage in a Prestige Industrial District the thus gross floor area is estimated to be 72,660 m² in the first case and 105,940 m² in the second.

Worksheet No. 4 - Transportation

It is assumed that the commercial uses, the public elementary school and the church are local uses and all their trip attractions are local trips, not to be included in Section B of Worksheet No.4. The separate school in Alternative 2A is included in the trip attraction section because it is assumed to draw most of its students from outside the secondary plan area.

The regional population of 410,045 was obtained from the Regional Planning Department. The modal split of 12% and the average car occupancy factor of 1.4 were obtained from recent local transportation studies. The average trip length of 8.4 km was obtained from Table E5.

Worksheet No. 5 - Construction Energy

The unit areas for the residential buildings in Alternative 2A are from the +20% section of Table A6. The base unit areas from Table A6 are used in the second alternative. Each unit area is

multiplied by the number of units shown on Worksheet No.2. The gross floor areas of commercial and institutional uses are taken from Worksheet No.2 and industrial gross floor areas were calculated in the discussion for Worksheet No.3. The church/day-care centre was assumed to be similar to educational uses for construction energy.

The length of road is used to estimate the length of services to be built. The values of 11,300 m for 2A and 8,100 m for 2B were obtained from the draft plans of subdivision. It is assumed that full municipal services will be installed, with storm sewers rather than drainage ditches.

Worksheet No. 6 - Operation of Services

The information from Column 2 is taken from Worksheets 1, 2 and 3. A church is assumed to use few services and, therefore, the office service energy coefficient was selected.

Worksheet No. 7 - Summary

From the results of the six basic worksheets the total annual energy consumption for the construction and operation of the development in Alternative 2A and 2B is estimated. Indicators are also calculated to provide a basis for comparison.

4.3.3 Case Study Two - Conclusions

A review of the total annual energy consumption for each component in Alternatives 2A and 2B (see Worksheet No.7) shows few variations. Despite the 84% increase in the number of residential units in Alternative 2B, the proportions of residential energy use declined from 48.7% to 43.5% of total annual energy consumption. While part of this decline is due to the increase in industrial use, most can be attributed to a more efficient residential mix in Alternative 2B. Energy use per unit declined from 194 GJ/unit

in Alternative 2A to 110 GJ/unit in Alternative 2B. This 43% reduction was due to a 20% reduction in unit sizes, the improvement of insulation and selections of a housing mix with more multiple dwelling units.

The introduction of additional residential units with lower trip generation rates resulted in a drop of 14% in transportation energy consumption per square metre of development from 0.80 GJ/m² to 0.69 GJ/m².

From an energy consumption viewpoint, Alternative 2B would be preferred over Alternative 2A because of a more energy-efficient housing mix accommodating a significantly larger population. An 85% increase in housing units and a 45% increase in industrial space were accommodated with a net increase in total energy consumption of only 17%. This figure may be conservative as the increase in residential density may encourage improved transit service and thus a further reduction in energy consumption.

4.4 Case Study Three - Suburban Town Centre

This case study is an analysis of the energy use in two alternative designs for a suburban town centre development containing a wide variety of residential, commercial and institutional uses. The first alternative (3A) emphasizes office uses while the second alternative (3B) contains a larger retail commercial component. Both proposals contain new offices for the municipal government and school board and a number of other civic buildings.

For the purposes of this case study the suburban town centre is located in Kingston Township, adjacent to the City of Kingston. Local information is included in as many places as possible and it is assumed that the results of a town centre design study and regional transportation plan are available.

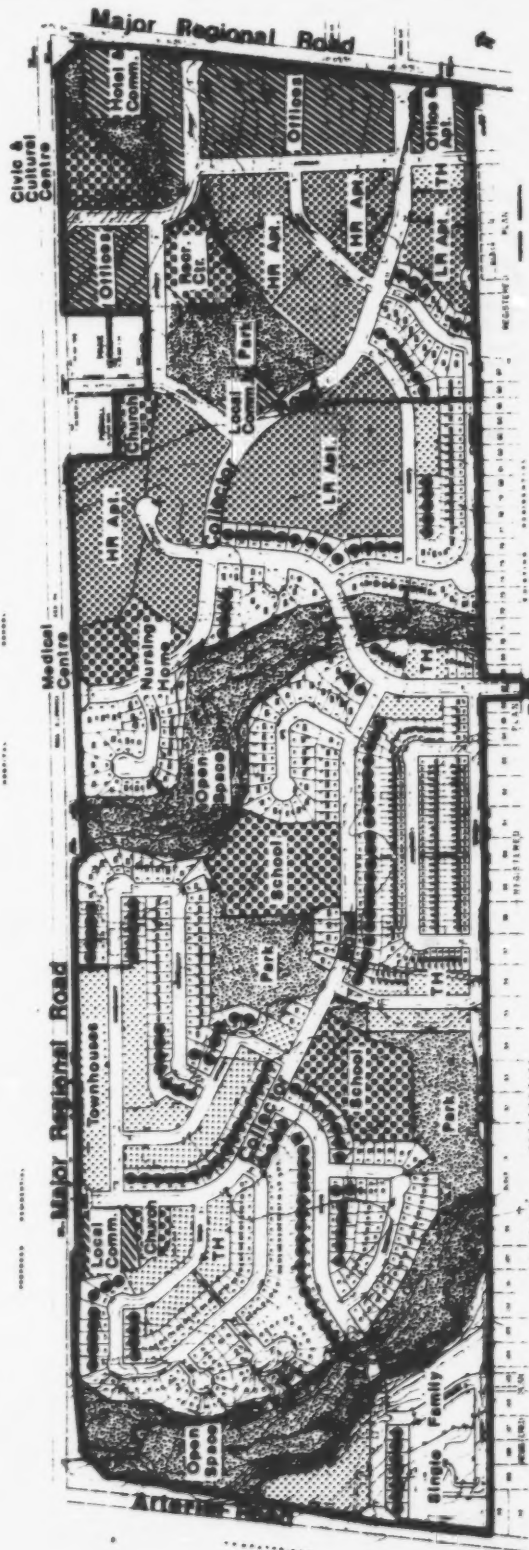
The property is bounded on two sides by major regional roads and by an arterial road and existing residential development on the other two sides. A regional hospital and secondary school are located opposite the proposed town centre site. The property is divided into three parcels by the valleys of two creeks and the remainder of the site is tableland with few development constraints. An existing firehall and police headquarters are presently located on the block outside the case study area.

4.4.1 Land Use

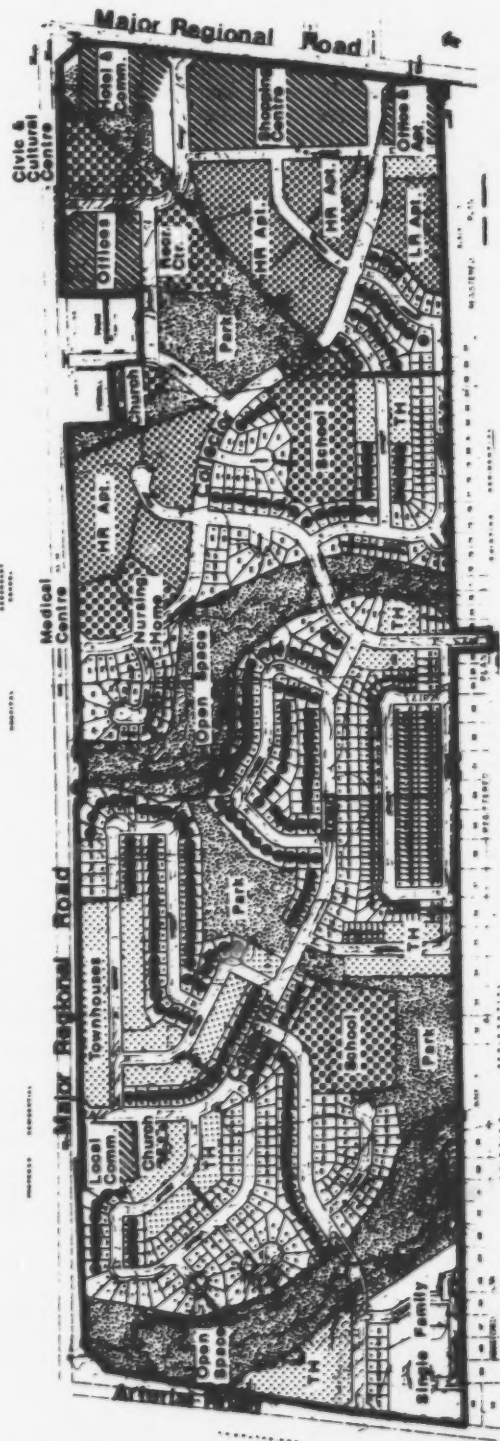
Alternative 3A contains 2,361 residential units, 62,000 m² of offices, 10,000 m² of retail space and a number of institutional uses. Alternative 3B uses fewer single family houses and places more emphasis on commercial uses (26,500 m²) with a shopping centre located adjacent to the municipal buildings.

The general location of the land uses is shown on Figure 4.4. The detailed distribution of land uses is:

<u>Land Use</u>	<u>Alternative 3A</u>		<u>Alternative 3B</u>	
	<u>Units</u>	<u>Hectares</u>	<u>Units</u>	<u>Hectares</u>
<u>1. Residential:</u>				
Single Family Detached	416	20.83	353	17.80
Semi-Detached	328	13.76	526	20.08
Street Townhousing	255	7.23	269	7.68
Block Townhousing	49	1.59	49	1.59
Low-rise Apartments	250	6.13	50	1.46
High-rise Apartments	1,003	9.67	920	8.90
<u>2. Commercial:</u>				
Local Commercial	-	1.21	-	0.91
Medical Offices	-	0.67	-	0.67
Commercial Offices	-	4.76	-	1.32
Hotel and Retail Commercial	-	1.67	-	1.67
Commercial/Residential	60	0.83	60	0.83
<u>3. Institutional:</u>				
Elementary Schools	-	4.45	-	4.86
Churches	-	0.84	-	0.84
Nursing Home	-	0.62	-	0.62
Municipal Offices & Cultural Centre	-	1.36	-	1.36
Recreation & Community Centre	-	1.05	-	1.05
<u>4. Open Space</u>				
Plaza and Square	-	0.97	-	0.97
Neighbourhood & Community Parks	-	8.14	-	8.78
Open Space	-	13.88	-	14.50
<u>5. Roads:</u>				
10,400 m - 3A	-	23.11	-	-
10,600 m - 3B	-	-	-	23.49
Totals	2,361	122.78	2,227	122.78



3A



3B

CASE STUDY 3 Suburban Town Centre



Marshall Macdon Monaghan Limited

Legend

- Semi-Detached
- TH Townhouses
- LR Apt. Low Rise Apartments
- HR Apt. High Rise Apartments

Figure

4.4

WORKSHEET NO. 1
RESIDENTIAL ENERGY CONSUMPTION

NO. 3A

3 Unit Type	Plan Data		Energy Coefficients (Btu/ft ² /year)					10 Total of Energy Coeff. (Btu/ft ² /year)	11 Annual Energy (kBtu)
	1 Number of Units	2 Square Footage (sq ft)	4 Space Heating	5 Water Heating	6 Ventilation	7 Lighting	8 Appliances		
Source	Year	Year	Table C-1	Table C-2	Table C-3	Table C-4	Table C-5	Sum 3-9	Sum 10-11

SP15									
SP16	46	97	132,000	94,000	24,400	21,000	184,700	85,500	
SP17	170	108	147,500	94,000	24,400	21,000	206,700	34,374	
SP18	200	103	135,900	94,000	24,400	21,000	130,400	38,180	
SP19	328	103	122,700	94,000	25,400	21,000	176,800	57,990	
SP20	304	99	101,200	77,000	17,500	21,000	141,400	44,810	
SP21									

SP22	250	100	68,000	4,900	12,400	17,000	102,300	25,575	
SP23	100	100	52,500	2,500	12,400	17,000	84,400	8,455	
SP24	60	100	52,500	2,500	12,400	17,000	84,400	5,064	
Total (SP15-24)	2364	31							

SP15 - Single Family 1-Step
SP16 - Single Family 2-Step
SP17 - Single Family 3-Step
SP18 - Single Family 4-Step
SP19 - Single Family 5-Step
SP20 - Single Family 6-Step
SP21 - Single Family 7-Step
SP22 - Single Family 8-Step
SP23 - Single Family 9-Step
SP24 - Single Family 10-Step

10 Total Annual Residential Energy Consumption (Sum of Rows in Column 9)

Enter in Column 3 of Worksheet No. 2

11 Residential Energy Consumption Indicator = 10 ÷ 31

Enter in Column 5 of Worksheet No. 2

WORKSHEET NO. 1
RESIDENTIAL ENERGY CONSUMPTION

NO. 3B

3 Unit Type	Plan Data		Energy Coefficients (Btu/ft ² /year)					10 Total of Energy Coeff. (Btu/ft ² /year)	11 Annual Energy (kBtu)
	1 Number of Units	2 Square Footage (sq ft)	4 Space Heating	5 Water Heating	6 Ventilation	7 Lighting	8 Appliances		
Source	Year	Year	Table C-1	Table C-2	Table C-3	Table C-4	Table C-5	Sum 3-9	Sum 10-11

SP15									
SP16	46	97	132,000	94,000	24,400	21,000	184,700	85,500	
SP17	150	108	147,500	94,000	24,400	21,000	206,700	30,530	
SP18	157	103	135,900	94,000	24,400	21,000	130,400	29,924	
SP19	526	103	122,700	94,000	25,400	21,000	176,800	92,997	
SP20	318	99	101,200	77,000	17,500	21,000	141,400	46,813	
SP21									

SP22	50	100	68,000	4,900	12,400	17,000	102,300	6,115	
SP23	920	100	52,500	2,500	12,400	17,000	84,400	76,448	
SP24	60	100	52,500	2,500	12,400	17,000	84,400	5,064	
Total (SP15-24)	2227	31							

SP15 - Single Family 1-Step
SP16 - Single Family 2-Step
SP17 - Single Family 3-Step
SP18 - Single Family 4-Step
SP19 - Single Family 5-Step
SP20 - Single Family 6-Step
SP21 - Single Family 7-Step
SP22 - Single Family 8-Step
SP23 - Single Family 9-Step
SP24 - Single Family 10-Step

10 Total Annual Residential Energy Consumption (Sum of Rows in Column 9)

Enter in Column 3 of Worksheet No. 2

11 Residential Energy Consumption Indicator = 10 ÷ 31

Enter in Column 5 of Worksheet No. 2

WORKSHEET NO. 2
COMMERCIAL AND INSTITUTIONAL ENERGY CONSUMPTION

NO. 3A

3 Unit Type	4 Square Footage (sq ft)	Energy Coefficients (Btu/ft ² /year)							10 Total of Energy Coeff. (Btu/ft ² /year)	11 Annual Energy (kBtu)
		5 Space Heating	6 Water Heating	7 Lighting	8 Ventilation	9 Refrigeration	10 Freezing	11 Power		
Source	Year	Table C-1	Table C-2	Table C-3	Table C-4	Table C-5	Table C-6	Table C-7	Sum 3-11	Sum 12-13

Office										
General	50,500								1000	50,500
Medical	5,000								1000	5,000
Municipal	9,000								1000	9,000

Retail										
Hotel	10,000								1100	11,000
Mall	6,000								1800	10,800
Food	2,100								3600	7,560
Local	2,000								1300	3,800

Institutions										
Church	3000								870	2,610
College	2,000								870	1,740
Library	4,000								870	4,090
Police	7,000								870	6,030
Post Office	6,000								2,800	16,800

Total Area (sq ft) 105,500

10 Commercial and Institutional Energy Consumption (Sum of Rows in Column 10)

Enter in Column 3 of Worksheet No. 2

11 Commercial Institutional Energy Consumption Indicator = 10 ÷ 31

Enter in Column 5 of Worksheet No. 2

WORKSHEET NO. 2
COMMERCIAL AND INSTITUTIONAL ENERGY CONSUMPTION

NO. 3B

3 Unit Type	4 Square Footage (sq ft)	Energy Coefficients (Btu/ft ² /year)							10 Total of Energy Coeff. (Btu/ft ² /year)	11 Annual Energy (kBtu)
		5 Space Heating	6 Water Heating	7 Lighting	8 Ventilation	9 Refrigeration	10 Freezing	11 Power		
Source	Year	Table C-1	Table C-2	Table C-3	Table C-4	Table C-5	Table C-6	Table C-7	Sum 3-11	Sum 12-13

Office										
General	16,700								1000	16,700
Medical	5,000								1000	5,000
Municipal	9,000								1000	9,000

Retail										
Hotel	21,000								1800	37,800
Mall	10,000								1100	11,000
Food	1,500								1300	2,050
Local	3,600								3600	12,960

Institutions										
Church	3000								870	2,610
College	2,000								870	1,740
Library	4,000								870	4,090
Police	7,000								870	6,030
Post Office	6,000								2,800	16,800

Total Area (sq ft) 87,000

10 Commercial and Institutional Energy Consumption (Sum of Rows in Column 10)

Enter in Column 3 of Worksheet No. 2

11 Commercial Institutional Energy Consumption Indicator = 10 ÷ 31

Enter in Column 5 of Worksheet No. 2

WORKSHEET NO. 4
TRANSPORTATION ENERGY CONSUMPTION

NO. 13A

A. Trip Productions

Building Type	1	2	3	4	5
Source	Dist.	Trips/ Dist.	Annual Trips	Persons/ Dist.	Total Persons
	Dist.	Tab. E1	1.0.2	Tab. E4	1.0.4
Single Family Detached	416	3500	1,452,600	3.5	1456
Single Family Attached	632	2912	1,840,384	3.5	2212
Low - Rise Apartment	250	1664	416,000	2.5	625
High Rise Apartment	1063	1144	1,216,072	2.5	2658

6 Total Annual Trip Productions = 4,965,064 7 Population = 6951

B. Trip Attractions

Land Use Activity (Excluding Local Uses)	9	10	11
Source	Floor Space (sq ft) or Occupancy	Average Trips Per Day/Person or Area Trips/sq ft/Person	Annual Trips
	Dist.	Table E2 & E3	9 x 10
1 Commercial Offices	50,000	36	1,818,000
2 Medical Offices	5,000	215	1,075,000
3 Municipal Offices	7,000	193	1,351,000
4 Hotel	180 rooms	3609	649,620
5 School (K)	500 students	260	130,000
6 Shopping Mall	6,000	270	1,620,000
7 Nursing Home	60 beds	871	52,260
8 Cultural and Rec. Center	11,700	70	819,000

Use circ. center
data from Table E2

12 Total Annual Trip Attractions = 9,562,880

WORKSHEET NO. 4
TRANSPORTATION ENERGY CONSUMPTION

NO. 13B

A. Trip Productions

Building Type	1	2	3	4	5
Source	Dist.	Trips/ Dist.	Annual Trips	Persons/ Dist.	Total Persons
	Dist.	Tab. E1	1.0.2	Tab. E4	1.0.4
Single Family Detached	363	3500	1,265,500	3.5	1236
Single Family Attached	844	2912	2,457,728	4.0	9376
Low - Rise Apartment	50	1664	83,200	2.1	105
High Rise Apartment	980	1144	1,121,120	2.1	2058

6 Total Annual Trip Productions = 4,925,622 7 Population = 6775

B. Trip Attractions

Land Use Activity (Excluding Local Uses)	9	10	11
Source	Floor Space (sq ft) or Occupancy	Average Trips Per Day/Person or Area Trips/sq ft/Person	Annual Trips
	Dist.	Table E2 & E3	9 x 10
1 Commercial Offices	16,200	36	583,200
2 Medical Offices	5,000	215	1,075,000
3 Municipal Offices	7,000	193	1,351,000
4 Shopping Center	24,500	180	4,405,000
5 Hotel	180 rooms	3609	649,620
6 Schools	500 students	260	130,000
7 Nursing Home	60 beds	871	52,260
8 Cultural - Rec. Center	11,700	70	819,000

12 Total Annual Trip Attractions = 9,266,080

WORKSHEET NO. 4 CONT
TRANSPORTATION ENERGY CONSUMPTION

NO. 13A

C. Internal and Total Trips

Source	33	34	35
Regional Population	Dist.		97,981
Internal Person Trips	(32 x 7) x 33		536,528
Total Person Trips	8 x 32 x 34		11,991,416

D. Passenger - Kilometres of Travel

Source	36	37	38	39	40
Average Trip Length (km)	Fig. E1 and Table E3		4.9		
Total Person - Kilometres	35 x 36		58,757,337		
Average B of Trips by Transit	Table E23		.026		
Total Transit Passenger - km	37 x 38		1,527,706		
Total Automobile Person - km	37 x 39		57,230,630		

E. Energy Consumption

Source	41	42	43	44	45
Energy Intensity (MJ/Pass. - km)	Table E7		1.0		
Transit Energy Consumption (MJ/Pass)	39 x 41		1,527,706		
Average Automobile Occupancy	Table E8		1.35		
Average Auto Energy Consumption (MJ/veh. - km)	Table E9		6.4		
Automobile Energy Consumption (MJ/Pass)	40 x 42 x 44		271,313,686		

46 Total Annual Transportation Energy (MJ/Year) (37 x 39 x 45) 272,841

Enter in Column 3 of Worksheet No. 7

F. Energy Consumption Indicator

Source	47	48	49	50
Total Residential Gross Floor Area (sq ft)	Sum of Column 2 x 3 in Worksheet No. 2		238,602	
Total Ind. / Bus. / Industrial (sq ft)	Sum of Column 6		27,700	
Total Gross Floor Area (sq ft)	47 + 48		266,302	
Transportation Energy Consumption Indicator (MJ/sq ft/year)	46 x 49		0.81	

Enter in Column 6 of Worksheet No. 7

WORKSHEET NO. 4 CONT
TRANSPORTATION ENERGY CONSUMPTION

NO. 13B

C. Internal and Total Trips

Source	33	34	35
Regional Population	Dist.		97,981
Internal Person Trips	(32 x 7) x 33		640,713
Total Person Trips	8 x 32 x 34		13,553,979

D. Passenger - Kilometres of Travel

Source	36	37	38	39	40
Average Trip Length (km)	Fig. E1 and Table E3		4.9		
Total Person - Kilometres	35 x 36		66,414,437		
Average B of Trips by Transit	Table E23		.026		
Total Transit Passenger - km	37 x 38		1,726,777		
Total Automobile Person - km	37 x 39		64,687,660		

E. Energy Consumption

Source	41	42	43	44	45
Energy Intensity (MJ/Pass. - km)	Table E7		1.0		
Transit Energy Consumption (MJ/Pass)	39 x 41		1,726,777		
Average Automobile Occupancy	Table E8		1.35		
Average Auto Energy Consumption (MJ/veh. - km)	Table E9		6.4		
Automobile Energy Consumption (MJ/Pass)	40 x 42 x 44		306,667,710		

46 Total Annual Transportation Energy (MJ/Year) (37 x 39 x 45) 308,394

Enter in Column 3 of Worksheet No. 7

F. Energy Consumption Indicator

Source	47	48	49	50
Total Residential Gross Floor Area (sq ft)	Sum of Column 2 x 3 in Worksheet No. 2		225,423	
Total Ind. / Bus. / Industrial (sq ft)	Sum of Column 6		81,300	
Total Gross Floor Area (sq ft)	47 + 48		307,303	
Transportation Energy Consumption Indicator (MJ/sq ft/year)	46 x 49		1.0	

Enter in Column 6 of Worksheet No. 7

WORKSHEET NO.5
CONSTRUCTION ENERGY CONSUMPTION

NO. 13A

1	2	3	4	5	6
Land Use Type	Gross Building Area (Sf)	Energy per (Sf/yr)	Energy by Type (Btu)	Project Life (Years)	Annual Energy (Btu/yr)
	Table F1	Table F2	Table F3	Table F4	Table F5
Construction of Buildings					
Residential - Single Family	43,427	0-1	354,718	50	79,541
Residential - Two-Four Family	63,940	7-2	460,936	50	91,990
Residential - Apartment	54,300	0-4	1,142,820	50	22,058
Commercial - Office	66,500	10-9	1,844,250	50	23,625
Commercial - Retail	19,100	10-9	808,190	30	6,340
Educational	3,000	15-9	47,300	50	254
Hospital	6,000	15-9	118,800	50	2,376
Industrial					
Other	13,700	15-9	217,830	50	4,357
Total Gross Building Area	342,900		Total Annual Building Construction Energy (Btu/yr)		76,543

7	8	9	10	11	12
Major Service Types	Length of Service (Yr)	Energy/Ft (Btu/Sf)	Energy by Type (Btu)	Project Life (Years)	Annual Energy (Btu/yr)
	Table F6	Table F7	Table F8	Table F9	Table F10
Construction of Services					
Base	10,400	3-0	31,200	25	1245
Water	10,400				
Sanitary Sewers	10,400				
Stormwater Piping	10,400				
Stormwater Detention	0				
Wastewater Treatment	10,400				
Sanitary Services	10,400				
All Piped Services	10,400	5-64	58,656	100	587
Total Annual Service Construction Energy (Btu/yr)					1835
Total Annual Construction Energy Consumption (7 + 6) - 3600					78
Enter in Column 3 of Worksheet No. 7					
Construction Energy Consumption Indicator (15 + Total Gross Building Area) - 6300/yr					-0002
Enter in Column 6 of Worksheet No. 7					

WORKSHEET NO.5
CONSTRUCTION ENERGY CONSUMPTION

NO. 13B

1	2	3	4	5	6
Land Use Type	Gross Building Area (Sf)	Energy per (Sf/yr)	Energy by Type (Btu)	Project Life (Years)	Annual Energy (Btu/yr)
	Table F1	Table F2	Table F3	Table F4	Table F5
Construction of Buildings					
Residential - Single Family	34,835	0-1	238,347	50	5907
Residential - Two-Four Family	85,640	7-2	616,752	50	18,336
Residential - Apartment	103,000	0-4	1,142,820	50	17,208
Commercial - Office	28,200	10-9	532,980	50	10,470
Commercial - Retail	34,100	10-9	303,430	30	13,116
Educational	3,000	15-9	47,300	50	254
Hospital	6,000	15-9	118,800	50	2,376
Industrial					
Other	13,700	15-9	217,830	50	4,357
Total Gross Building Area	312,433		Total Annual Building Construction Energy (Btu/yr)		67,079

7	8	9	10	11	12
Major Service Types	Length of Service (Yr)	Energy/Ft (Btu/Sf)	Energy by Type (Btu)	Project Life (Years)	Annual Energy (Btu/yr)
	Table F6	Table F7	Table F8	Table F9	Table F10
Construction of Services					
Base	10,400	3-0	31,200	25	1272
Water	10,400				
Sanitary Sewers	10,400				
Stormwater Piping	10,400				
Stormwater Detention	0				
Wastewater Treatment	10,400				
Sanitary Services	10,400				
All Piped Services	10,400	5-64	59,784	100	598
Total Annual Service Construction Energy (Btu/yr)					1870
Total Annual Construction Energy Consumption (7 + 6) - 3600					63
Enter in Column 3 of Worksheet No. 7					
Construction Energy Consumption Indicator (15 + Total Gross Building Area) - 6300/yr					-0002
Enter in Column 6 of Worksheet No. 7					

WORKSHEET NO.6
OPERATION OF SERVICES ENERGY CONSUMPTION

NO. 13A

1	2	3	4
Land Use Type	Number of Units or Area	Service Energy Factor	Annual Energy Consumption
Source	Worksheets 1, 2, and 3	Table G1	Table G2
Residential			
Single Family	616 units	2,000	832,000
Two-Four Family	682 units	1,500	348,000
Apartment	1313 units	1,500	1,969,500
Commercial - Office	62,500 m ²	11	687,500
Commercial - Retail	19,100 m ²	52	993,200
Educational	2 schools (1000 std)	200,000 per school	200,000
Hospital	60 beds	1,800,000 @ 10%	180,000
Industrial - Light			
Industrial - Heavy			
Other	13,700 m ²	11	150,700

Sub Total (Sum of Column 4) 5,960,900

Energy Consumption Coefficiency Factor (See Section 3.5.2) 1-15

Total Annual Energy Consumption for Operation of Services (14) - 3600 6855

Enter in Column 3 of Worksheet No. 7

Operation of Services Energy Indicator (17 + Sum of Column 3 Worksheet No. 5) 0-02

Enter in Column 6 of Worksheet No. 7

WORKSHEET NO.6
OPERATION OF SERVICES ENERGY CONSUMPTION

NO. 13B

1	2	3	4
Land Use Type	Number of Units or Area	Service Energy Factor	Annual Energy Consumption
Source	Worksheets 1, 2, and 3	Table G1	Table G2
Residential			
Single Family	353 units	2,000	706,000
Two-Four Family	844 units	1,500	1,266,000
Apartment	1030 units	1,500	1,545,000
Commercial - Office	28,200 m ²	11	310,200
Commercial - Retail	34,100 m ²	52	1,777,200
Educational	2 schools (1000 std)	200,000 per school	200,000
Hospital	60 beds	1,800,000 @ 10%	180,000
Industrial - Light			
Industrial - Heavy			
Other	13,700 m ²	11	150,700

Sub Total (Sum of Column 4) 6,235,000

Energy Consumption Coefficiency Factor (See Section 3.5.2) 1-15

Total Annual Energy Consumption for Operation of Services (14) - 3600 7170

Enter in Column 3 of Worksheet No. 7

Operation of Services Energy Indicator (17 + Sum of Column 3 Worksheet No. 5) 0-02

Enter in Column 6 of Worksheet No. 7

WORKSHEET NO.7
ENERGY CONSUMPTION - SUMMARY

NO. 11

Line No.	Category	Utilization Source	Total Annual Energy Consumption GJ/year	Distribution % (Total of 100)	Utilization Source (Indicators)	Energy Consumption Indicators
----------	----------	--------------------	---	-------------------------------	---------------------------------	-------------------------------

7	Residential	No. 3 Line 30	299,194	42.4	No. 3 Line 32	127 GJ/year
8	Commercial and Institutional	No. 2 Line 33	126,390	18.0	No. 2 Line 34	1.2 GJ/year
9	Industrial	No. 3 Line 0	0	-	No. 3 Line 0	- GJ/year
10	Transportation	No. 4 Line 35	292,041	38.6	No. 4 Line 36	0-01 GJ/year
11	Construction	No. 5 Line 36	75	-	No. 5 Line 36	-0002 GJ/year
12	Generation of Services	No. 6 Line 7	6855	1.0	No. 6 Line 8	0-02 GJ/year

Total Annual Energy Consumption
of Process Development
(Sum of Column 3) 705,930 GJ/year

WORKSHEET NO.7
ENERGY CONSUMPTION - SUMMARY

NO. 12

Line No.	Category	Utilization Source	Total Annual Energy Consumption GJ/year	Distribution % (Total of 100)	Utilization Source (Indicators)	Energy Consumption Indicators
----------	----------	--------------------	---	-------------------------------	---------------------------------	-------------------------------

7	Residential	No. 3 Line 30	295,539	40.2	No. 3 Line 32	135 GJ/year
8	Commercial and Institutional	No. 2 Line 33	124,220	16.9	No. 2 Line 34	1.4 GJ/year
9	Industrial	No. 3 Line 0	0	-	No. 3 Line 0	- GJ/year
10	Transportation	No. 4 Line 35	308,394	41.9	No. 4 Line 36	1.0 GJ/year
11	Construction	No. 5 Line 36	69	-	No. 5 Line 36	-0002 GJ/year
12	Generation of Services	No. 6 Line 7	7,170	1.0	No. 6 Line 8	0-02 GJ/year

Total Annual Energy Consumption
of Process Development
(Sum of Column 3) 735,392 GJ/year

4.4.2 Calculation of Energy Consumption

The following sections describe inputs required to complete Worksheets 1 through 7 for both alternatives.

Worksheet No. 1 - Residential Energy Use

The single family units are assumed to include the following types of houses:

	<u>3A</u>	<u>3B</u>
regular bungalows	46	46
two-storey houses	200	157
split-level houses	<u>170</u>	<u>150</u>
	416	353

These units are assumed to have the characteristics of the basic houses in Table A5. The space heating coefficients for these houses are obtained directly from Table A1.

The apartment units are standard and will have the space heating characteristics in Table A1. The remainder of Worksheet No.1 is completed using the information found in Section A of the Catalogue.

Worksheet No. 2 - Commercial and Institutional Uses

The types of office uses located on the site and their respective areas are estimated using information in the town centre design study. Thus -

	<u>3A</u>	<u>3B</u>
Municipal offices	- 7,000 m ²	7,000 m ²
Retail offices (100% coverage)	- 47,500 m ²	13,200 m ²
Medical offices (75% coverage)	- 5,000 m ²	5,000 m ²
Residential/Office block	- 2,000 m ²	2,000 m ²
Local commercial offices	- <u>1,000</u> m ²	<u>1,000</u> m ²
Total:	- 62,500 m ²	28,200 m ²

The proposed shopping centre in Alternative 3B is 3.52 ha with an estimated coverage of 50%, and a gross retail floor space of 17,500 m². It would contain a 3,500 m² supermarket and 14,000 m² of retail space which could be connected to the 7,000 m² retail space in the hotel complex.

The hotel is assumed to have 180 guest rooms with a total floor area of 10,000 m² which is connected to 6,000 m² of general retail space and a 1,000 m² food store in Alternativa 3A.

Local commercial uses include a 0.81 ha and a 0.40 ha site, both at 33% coverage (4,100 m² and 2,600 m²) which included:

	<u>3A</u>	<u>3B</u>
Food stores	- 1,100 m ²	1,000 m ²
Local offices	- 1,000 m ²	1,000 m ²
Retail commercial	- <u>2,000</u> m ²	<u>1,500</u> m ²
Total	- 4,100 m ²	2,600 m ²

In summary, it is assumed that the following retail commercial uses will be built:

	<u>3A</u>	<u>3B</u>
Shopping centre (food)	2,000 m ²	3,500 m ²
Convenience food	100 m ²	100 m ²
Shopping centre (retail)	-	14,000 m ²
Hotel retail mall	6,000 m ²	7,000 m ²
Local retail	<u>2,000</u> m ²	<u>1,000</u> m ²
Total	10,100 m ²	26,100 m ²

Institutional uses include two elementary schools of 500 students each (3,000 m² total area), two churches (assumed to 1,000 m² each), a recreation and community centre of 4,700 m², a cultural centre of 7,000 m² and a nursing home on a 0.6 ha site. This home is assumed to include 6,000 m² (60 units) at 100% coverage.

Churches, recreation/community centres and cultural centres are assumed to be similar to elementary schools in energy consumption. The nursing home is assigned the unit energy value used for hospitals.

Worksheet No. 4 - Transportation

The local commercial uses, one public school and local office uses are assumed to produce internal trips and are not included in the worksheet for trip attraction. The second elementary school in each alternative is assumed to be a separate school board facility serving a large area and is included in the worksheet. Medical and municipal government offices are included as separate categories of trip attractions because they have larger trip generations.

The local planning department provided the regional population count (97,981) and the following estimates of unit occupancy:

single family detached	-	3.5 persons per unit
single family attached	-	4.0 persons per unit
apartments	-	2.1 persons per unit

These unit occupancy figures are used in Column 4 of Worksheet No. 4.

The trip length of 4.9 km was obtained from the regional transportation study. The town centre is located close to the City of Kingston boundaries and intended to become the focus of the Kingston Township transit system. It contains a large number of higher density dwellings, which produce more transit trips. For these reasons, a transit trip rate of 20 trips per capita was selected, in comparison with rates of 9.4 trips/capita in the rest of the Township and 44.3 trips/capita in the City of Kingston.

Worksheet No. 5 - Construction Energy

The unit areas for the residential buildings are obtained from Table A5 and the number of units can be found in Worksheet No.1. It is assumed that the hotel will be similar to retail uses and that the nursing home will require construction energy similar to a hospital, on a unit basis. It is also estimated that the cultural centre, churches and recreation and community centre will be comparable to educational uses for this worksheet.

The road length is used as an estimate of the length of services to be installed in each case. Full municipal services are assumed for the worksheet.

Worksheet No. 6 - Operation of Services

The information from Column 2 is taken from Worksheets 1 and 2. The churches, cultural centre and recreation and community centre are assumed to use few municipal services thus the office energy coefficient was selected. The nursing home is assumed to contain 60 beds and is estimated to use 10% of the service energy required by the 500 bed hospital listed in Table G5.

The energy consumption contingency factor was assumed to be 1.15.

Worksheet No. 7 - Summary

From the results of the six basic worksheets the total annual energy consumption for the construction and operation of Alternative 3A or 3B is estimated. Indicators are calculated for each worksheet to provide a means of comparison between the alternatives.

4.4.3 Case Study Three - Conclusions

A comparison between the indicators for Case Studies 3A and 3B shows a general increase in energy consumption from 3A to 3B. This is caused by the redistribution of land use between uses that have different sensitivities to energy consumption. A slight increase (4%) in residential energy consumption is a result of redistribution in the mix of housing types.

A significant increase (31%) in the Commercial indicator is a result of shifting from primarily office space to a shopping centre with a reduced office component. The impact of this shift in land use is primarily felt in the Transportation sector where the indicator has increased 24% from 0.89 to 0.99. This is due to the fact that shopping centres have much higher trip generation characteristics than offices. This should not be interpreted as a criticism of larger commercial facilities but an indication of their impact on energy consumption and that consideration should be given to improved transit service to such facilities.

5.0 ENERGY SAVING MEASURES

5.1 Introduction

The energy saving measures which are discussed in this chapter relate to the methodology used in this manual and are indicative of the areas in which changes can be made to save energy consumption in new development. The Case Studies in Chapter 4 illustrate a number of the areas where savings can be made.

Some of the sectors analyzed in this manual offer significantly more opportunities for energy conservation. Other areas where energy efficiency is possible, may not be illustrated in the manual because of the macro-level analysis used. For example, it is possible to select a significantly more energy and cost-efficient luminaire for street lighting. However, the amount of energy used in street lighting is relatively so small (0.15 GJ/year for Case Study 1) that it is not significant in our analysis.

This chapter will suggest areas for energy conservation in each sector for which worksheets were developed in Chapter 3.

5.2 Suggested Areas for Energy Conservation

The effectiveness of an energy conservation programme depends upon the amount of energy being used in the target sectors, the proportional reduction possible and the ease of implementation. In some areas such as services, the municipality has considerable control over implementation but the total savings may be small. In other areas where there may be considerable potential, such as improving heating system efficiency, the municipality is unlikely to have jurisdiction.

Transportation and space heating have been identified as the two aspects of new development which offer the greatest potential for energy conservation and are capable of being directly influenced by municipal planners. They are typically the two largest users of energy in the urban area. Figure 5.1 illustrates the relationship of urban characteristics with the sectors addressed in this manual and indicates the areas where municipal planners can have some effect.

This manual can be used to estimate the effects of changes of building form, density and mix of uses. The case studies in Chapter 4 provide an analysis of examples which demonstrate the impact of changes in these factors.

Local development patterns, siting and landscaping are micro-level design issues which cannot effectively be addressed using this manual. Techniques for energy conservation in these areas include landscaping, building orientation, use of natural slopes and barriers for wind and sun control, and orientation of streets to encourage passive solar heating. These and other micro design techniques are extensively discussed elsewhere in the Ministry of Energy's series of handbooks for planners and in the references listed at the end of this report.

5.2.1 Residential - Worksheet No.1

The residential sector is typically the largest consumer of energy in an urban area. Improvements in space heating can result in significant overall savings of energy. This can be accomplished by building more energy-efficient housing and by improving construction practices so that the performance standards specified in building codes are realized.

The modest improvements to building standards shown in Table B1 would result in significant savings of energy used for space heating. Table A9 in the data catalogue can be used to analyze the effects upon residential space heating of adjustments to building insulation and ventilation.

FIGURE 5.1

AREAS FOR ENERGY CONSERVATION

Building Factors Energy Use Factors								
	Location	Density	Mix of Uses	Subdivision Design	Building Type and Size	Building Design	Siting and Landscaping	Building Operation
Residential		●	●	●	●	●	●	○
Commercial & Institutional			●		●	●	●	○
Industrial			●		●	●		○
Transportation	●	●	●	●				
Construction					●	●		
Operation of Services		●	●					

		PLANNING INFLUENCE		
		Large	Some	None
Energy Savings	Large	●	●	○
	Some	●	●	○
	Small	●	●	○

Table 5.1 illustrates the effect of increasing all the insulation factors and selecting a low air exchange rate upon the six alternative unit types. For the purposes of this example, it is assumed that the units are located in the Toronto area. The percentage improvement in space heating is approximately 59% for all unit types.

TABLE 5.1
SPACE HEATING ADJUSTMENTS

<u>Unit Type</u>	<u>Existing Space Heating Factor MJ/Year</u>	<u>Improved Space Heating Factor MJ/Year</u>	<u>Improvement %</u>
L-Shaped One Storey	201,000	83,400	59%
Regular One Storey	126,300	52,400	59%
Split Level	141,100	59,000	58%
Two Storey	130,100	53,600	59%
Semi-Detached	117,400	48,200	59%
Row House	96,900	39,100	60%

Energy conservation in apartment buildings is a function of building operation and management and would require individual building analysis and a programme for management of building heating, ventilating and air conditioning systems.

A housing mix which favours building forms with minimum peripheral area and maximum common walls, produces significant space heating energy savings per sq. metre of residential development. For example a two-storey detached house in Toronto requires an average of 1,263 MJ/sq.m/year while a row house in Toronto uses 979 MJ/sq.m/year, a saving of 22%.

5.2.2 Commercial and Institutional Uses - Worksheet No.2

The commercial and institutional sector can also benefit from improved building standards for space heating. However, heat-energy management programs are likely to provide larger reductions in energy consumption for buildings with a number of users whose services are centrally provided. The potential for mixed use developments where waste heat from commercial operations such as restaurants, bakeries, cleaners, etc. can be used to heat residential and/or commercial facilities would significantly reduce total annual energy consumption.

Building systems such as fans, pumps and lighting are more important in commercial and institutional uses than in residential development. Selection of more efficient fixtures and systems, in combination with an energy management program may prove to be an effective conservation programme. The type of conservation programme needed will vary from building to building, but a complete energy audit is recommended as a first step.

5.2.3 Industrial - Worksheet No.3

Industrial energy use varies widely within industry groups according to the amount of process power used. Space heating is typically a small (less than 20%) portion of total industrial energy use, but improved building standards would result in improvements in this sector.

For significant reductions in industrial energy use, the process power usage of the industries must be improved by such techniques as making use of process heat for space heating, recycling of steam and waste materials, and designing processes which require less energy to produce the same product. Most of these measures are not within the jurisdiction of municipal planners.

The planning of industrial parks in locations adjacent to large heat generation sources, such as nuclear power plants, improves the possibility of more efficient use of waste energy. Direct access to major transportation facilities (road, rail and port) could also reduce energy consumption.

5.2.4 Transportation - Worksheet No. 4

The results of the transportation analysis clearly point out that public transit is significantly more energy efficient than travel by automobile.

Measures which increase the portion of transit riders (modal split) will result in significant energy savings. Planners can encourage the use of transit by designing developments which can be economically serviced by transit routes. In addition, it is necessary to provide sufficient density of potential riders and trip attractions to make transit routes economic.

Other energy saving possibilities which can be identified but will be difficult for the planner to directly influence include:

1. Increasing vehicle occupancy by car pooling and van pooling
2. Increasing vehicle efficiency by selection of smaller cars and improving vehicle energy efficiency.
3. Decreasing the average trip length by planning a more compact urban form.
4. Decreasing the number of trips by encouraging mixed uses which will permit multi function trips.

The effects of these measures upon total transportation energy consumption can be estimated using Worksheet No.4.

5.2.5 Construction - Worksheet No.5

The energy embodied in building materials and the energy directly used in the construction of buildings amounts to a very small portion (less than 1%) of total energy use when considered on an annual basis. Improvements in construction practices cannot be evaluated accurately using this manual. However, it is known that reduced development standards and substitution for construction materials which require large quantities of energy to manufacture, such as asphalt, can result in energy savings.

5.2.6 Operation of Services - Worksheet No.6

The operation of services comprises a small portion (1 - 2%) of total annual energy use. However, improvements to the efficiency of waste treatment systems and reductions in the volume of waste may result in energy savings which have economically realistic pay-back periods. Municipalities may wish to examine this sector because they have almost total control of the operation of services, while the responsibility for other sectors is spread among many individuals and corporations.



Data Catalogue



SECTION A

RESIDENTIAL ENERGY CONSUMPTION

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Table A1

AVERAGE SPACE HEATING ENERGY REQUIREMENTS
FOR RESIDENTIAL UNITS IN ONTARIO COMMUNITIES
(MJ/Unit/Year)

Town	Degree Days °C	Single Family Residential Units						Multiple Units	
		L-Shaped	Regular	Split-Level	Two Storey	Semi-Detached	Row	Low Rise	High Rise
Ailsa Craig	4,055	199,700	125,500	140,200	129,200	116,600	92,200	64,700	49,900
Ajax	4,167	205,200	128,900	144,100	132,800	119,900	98,900	66,500	51,200
Alexandria	4,580	225,500	141,700	158,300	145,900	131,700	108,700	73,000	56,300
Alliston	4,520	222,600	139,900	156,300	144,000	130,000	107,300	72,100	55,600
Almonte	4,740	233,400	146,700	163,900	151,000	136,300	112,500	75,600	58,300
Ansonville	6,220	306,300	192,500	215,000	198,200	178,900	147,600	99,200	76,500
Armstrong	6,892	339,400	213,300	238,300	219,600	198,200	163,600	109,900	84,800
Arnprior	4,800	236,400	148,500	166,000	153,000	138,100	113,900	76,600	59,000
Atikokan	6,040	297,400	186,900	208,800	192,500	173,700	143,300	96,300	74,300
Aurora	4,300	211,700	133,100	148,700	137,000	123,700	102,000	68,600	52,900
Bancroft	4,960	244,200	153,500	171,500	158,100	142,700	117,700	79,100	61,000
Barrie	4,470	220,100	138,300	154,500	142,400	128,600	106,100	71,300	55,000
Barriefield	4,240	208,800	131,200	146,600	135,100	122,000	100,600	67,600	52,100
Beaverton	4,580	225,500	141,700	158,300	145,900	131,700	108,700	73,000	56,300
Belleville	4,190	206,300	129,700	144,900	133,500	120,500	99,400	66,800	51,500
Belmont	3,980	196,000	123,200	137,600	126,800	114,500	94,500	63,500	48,900
Bowmanville	4,130	203,400	127,800	142,800	131,600	118,800	98,000	65,900	50,800
Bracebridge	4,800	236,400	148,500	166,000	153,000	138,100	113,900	76,600	59,000
Bradford	4,410	217,200	136,500	152,500	140,500	126,800	104,700	70,300	54,200
Brampton	4,200	206,800	130,000	145,200	133,800	120,800	99,700	67,000	51,700
Brantford	3,920	193,000	121,300	135,500	124,900	112,800	93,000	62,500	48,200
Brighton	4,240	208,800	131,200	146,600	135,100	122,000	100,600	67,600	52,100
Brockville	4,300	211,700	133,100	148,700	137,000	123,700	102,000	68,600	52,900
Brooklin	4,240	208,800	131,200	146,600	135,100	122,000	100,600	67,600	52,100
Burks Falls	5,070	249,700	156,900	175,300	161,600	145,800	120,300	80,900	62,400
Burlington	3,700	182,200	114,500	127,900	117,900	106,400	87,800	49,000	45,500
Caledonia	3,920	193,000	121,300	135,500	124,900	112,800	93,000	62,500	48,200
Cambridge	4,130	203,400	127,800	142,800	131,600	118,800	98,000	65,900	50,800
Campbellford	4,410	217,200	136,500	152,500	140,500	126,800	104,700	70,300	54,200
Camp Borden	4,470	220,100	138,300	154,500	142,400	128,600	106,100	71,300	55,000
Cannington	4,470	220,100	138,300	154,500	142,400	128,600	106,100	72,300	55,000
Carleton Place	4,690	230,900	145,100	162,100	149,400	134,900	111,300	74,800	57,700
Cavan	4,470	220,100	138,300	154,500	142,400	128,600	106,100	71,300	55,000
Centralia	3,940	194,000	121,900	136,200	125,500	113,300	93,500	62,800	48,500
Chapleau	5,950	293,000	184,100	205,700	189,600	171,100	141,200	94,900	73,200
Chatham	3,530	173,800	109,200	122,000	112,500	101,500	83,800	56,300	43,400
Chelmsford	5,920	291,500	183,200	204,700	188,600	170,300	140,500	94,400	72,800
Chelsey	4,240	208,800	131,200	146,600	135,100	122,000	100,600	67,600	52,100
Clinton	4,130	203,400	127,800	142,800	131,600	118,800	98,000	65,900	50,800
Coboconk	4,740	233,400	146,700	163,900	151,000	136,300	112,500	75,600	58,300
Cobourg	4,190	206,300	129,700	144,900	133,500	120,500	99,400	66,800	51,500

Table A1
(Continued)
AVERAGE SPACE HEATING ENERGY REQUIREMENTS
FOR RESIDENTIAL UNITS IN ONTARIO COMMUNITIES
(MJ/Unit/Year)

Town	Degree Days °C	Single Family Residential Units						Multiple Units	
		L-Shaped	Regular	Split-Level	Two Storey	Semi-Detached	Row	Low Rise	High Rise
Cochrane	6,230	306,800	192,800	215,400	198,500	179,200	147,900	99,400	76,600
Colborne	4,190	206,300	129,700	144,900	133,500	120,500	99,400	66,800	51,500
Collingwood	4,580	225,500	141,700	158,300	145,900	131,700	108,700	73,000	56,300
Cornwall	4,470	220,100	138,300	154,500	142,400	128,600	106,100	71,300	55,000
Deep River	5,180	155,100	160,300	179,100	165,100	149,000	122,900	82,600	63,700
Deseronto	4,080	200,900	126,200	141,100	130,000	117,400	96,800	65,100	50,200
Dorchester Sta.	4,030	198,400	124,700	139,300	128,400	115,900	95,600	64,300	49,600
Doiron	5,890	290,000	182,300	203,600	187,700	169,400	139,800	93,900	72,400
Dresden	3,700	182,200	114,500	127,900	117,900	106,400	87,800	59,000	45,500
Dryden	6,080	299,400	188,100	210,200	193,700	174,900	144,300	97,000	74,800
Dunbarton	4,030	198,400	124,700	139,300	128,400	115,900	95,600	64,300	49,600
Dunnville	3,810	187,600	117,900	131,700	121,400	109,600	90,400	60,800	46,900
Durham	4,620	227,500	143,000	159,700	147,200	132,900	109,600	73,700	56,800
Dutton	3,750	184,700	116,000	129,600	119,500	107,900	89,000	59,800	46,100
Earlton	5,866	288,800	181,500	202,800	186,900	168,700	139,200	93,600	72,100
Edison	6,000	295,400	185,700	207,400	191,200	172,600	142,400	95,700	73,800
Elmvale	4,580	225,500	141,700	158,300	145,900	131,700	108,700	73,000	56,300
Embro	4,130	203,400	127,800	142,800	131,600	118,800	98,000	65,900	50,800
Englehart	5,950	293,000	184,100	205,700	189,600	171,100	141,200	94,900	73,200
Espanola	5,070	249,700	156,900	175,300	161,600	145,800	120,300	80,900	62,400
Exeter	4,080	200,900	126,200	141,100	130,000	117,400	96,800	65,100	50,200
Fenelon Falls	4,690	230,900	145,100	162,100	149,400	134,900	111,300	74,800	57,700
Fergus	4,610	227,000	142,600	159,400	146,900	132,600	109,400	73,500	56,700
Fonthill	3,700	182,200	114,500	127,900	117,900	106,400	87,800	59,000	45,500
Forest	3,830	188,600	118,500	132,400	122,000	110,200	90,900	61,100	47,100
Fort Erie	3,590	176,800	111,100	124,100	114,400	103,300	85,200	57,300	44,100
Fort Frances	5,830	287,100	180,400	201,600	185,800	167,700	138,400	93,000	71,700
Gananoque	4,240	208,800	131,200	146,600	135,100	122,000	100,600	67,600	52,100
Georgetown	4,250	209,300	131,500	146,900	135,400	122,200	100,900	67,800	52,300
Geraldton	6,550	322,500	202,700	226,500	208,700	188,400	155,400	104,500	80,600
Glencoe	3,810	187,600	117,900	131,700	121,400	109,600	90,400	60,800	46,900
Goderich	4,190	206,300	129,700	144,900	133,500	120,500	99,400	66,800	51,500
Gore Bay	4,910	241,800	151,900	169,800	156,500	141,200	116,500	78,300	60,400
Graham	6,470	318,600	200,200	223,700	206,200	186,100	153,500	103,200	79,600
Gravenhurst	4,740	233,400	146,700	163,900	151,900	136,300	112,500	75,600	58,300
Grimsby	3,580	176,300	110,800	123,800	114,100	103,000	85,000	57,100	44,000
Guelph	4,220	207,800	130,600	145,900	134,500	121,400	100,100	67,300	51,900
Guthrie	4,520	222,600	139,900	156,300	144,000	130,000	107,300	72,100	55,600
Hagersville	3,920	193,000	121,300	135,500	124,900	112,800	93,000	62,500	48,200
Haileybury	5,830	287,100	180,400	201,600	185,800	167,700	138,400	93,000	71,700

Table A1
(Continued)
AVERAGE SPACE HEATING ENERGY REQUIREMENTS
FOR RESIDENTIAL UNITS IN ONTARIO COMMUNITIES
(MJ/Unit/Year)

Town	Degree Days °C	Single Family Residential Units						Multiple Units	
		L-Shaped	Regular	Split-Level	Two Storey	Semi-Detached	Row	Low Rise	High Rise
Haliburton	4,920	242,300	152,200	170,100	156,800	141,500	116,800	78,500	60,500
Hamilton	3,710	182,700	114,800	128,300	118,200	106,700	88,000	59,200	45,600
Hanover	4,350	214,200	134,600	150,400	138,600	125,100	103,200	69,400	53,500
Hastings	4,470	220,100	138,300	154,500	142,400	128,600	106,100	71,300	55,000
Hawkesbury	4,800	236,400	148,400	166,000	153,000	138,100	113,900	76,600	59,000
Hearst	6,500	320,100	201,100	224,700	207,100	187,000	154,300	103,700	79,900
Money Harbour	4,580	225,500	141,700	158,300	145,900	131,700	108,700	73,000	56,300
Hornepayne	6,580	324,000	203,600	227,500	109,700	189,300	156,200	104,900	80,900
Huntsville	4,760	234,400	147,300	164,600	151,700	136,900	113,000	75,900	58,500
Ingersoll	4,030	198,400	124,700	139,300	128,400	115,900	95,600	64,300	49,600
Jarvis	3,860	190,100	119,400	133,500	123,000	111,000	91,600	61,600	47,500
Jellicoe	6,480	319,100	200,500	224,000	106,500	186,400	153,800	103,300	79,700
Kapuskasing	6,366	313,500	197,000	220,100	202,900	183,100	151,100	101,500	78,300
Kemptville	4,520	222,600	139,900	156,300	144,000	130,000	107,300	72,100	55,600
Kenora	5,932	292,100	183,600	205,100	189,000	170,600	140,800	94,600	73,000
Killaloe Sta.	4,940	243,300	152,900	170,800	157,400	142,100	117,200	78,800	60,800
Kincardine	4,240	208,800	131,200	146,600	135,100	122,000	100,600	67,600	52,100
Kingston	4,266	210,100	132,000	147,500	135,900	122,700	101,200	68,000	52,500
Kinmount	4,800	236,400	148,500	166,000	153,000	138,100	113,900	76,600	59,000
Kirkland Lake	6,150	302,800	190,300	212,600	196,000	176,900	146,000	98,100	75,600
Kitchener	4,110	202,400	127,200	142,100	131,000	118,200	97,500	65,500	50,500
Lakefield	4,630	228,000	143,300	160,100	147,500	133,200	109,900	73,800	56,900
Lansdowne House	7,110	350,100	220,000	245,800	226,600	204,500	168,700	113,400	87,400
Leamington	3,560	175,300	110,200	123,100	113,400	102,400	84,500	56,800	43,800
Lindsay	4,580	225,500	141,700	158,300	145,900	131,700	108,700	73,000	56,300
Lions Head	4,350	214,200	134,600	150,400	138,600	125,100	103,200	69,400	53,500
Listowel	4,630	228,000	143,300	160,100	147,500	133,200	109,900	73,800	56,900
London	4,068	100,300	125,900	140,600	129,600	117,000	96,500	64,900	50,000
Lucan	4,030	198,400	124,700	139,300	128,400	115,900	95,600	64,300	49,600
Maitland	4,300	211,700	133,100	148,700	137,000	123,700	102,000	68,600	52,900
Markdale	4,690	230,900	145,100	162,100	149,400	134,900	111,300	74,800	57,700
Martin	6,330	311,700	195,900	218,800	201,700	182,100	150,200	101,000	77,800
Matheson	6,220	306,300	192,500	215,000	198,200	178,900	147,600	99,200	76,500
Mattawa	5,340	262,900	165,200	184,600	170,200	153,600	126,700	85,200	65,700
Midland	4,580	225,500	141,700	158,300	145,900	131,700	108,700	73,000	56,300
Milton	4,080	200,900	126,200	141,100	130,000	117,400	96,800	65,100	50,200
Milverton	4,520	222,600	139,900	156,300	144,000	130,000	107,300	72,100	55,600
Minden	4,850	238,800	150,100	167,700	154,500	139,500	115,100	77,300	59,600
Mississauga	3,810	187,600	117,900	131,700	121,400	109,600	90,400	60,800	46,900
Mitchell	4,400	216,700	136,100	152,100	140,200	126,600	104,400	70,200	54,100
Moosonee	6,931	341,300	214,500	239,600	220,900	199,400	164,500	110,500	85,200

Table A1
(Continued)
AVERAGE SPACE HEATING ENERGY REQUIREMENTS
FOR RESIDENTIAL UNITS IN ONTARIO COMMUNITIES
(MJ/Unit/Year)

Town	Degree Days °C	Single Family Residential Units						Multiple Units	
		L-Shaped	Regular	Split- Level	Two Storey	Semi- Detached	Row	Low Rise	High Rise
Morrisburg	4,410	217,200	136,500	152,500	140,500	126,800	104,700	70,300	54,200
Mount Forest	4,755	234,100	147,100	164,400	151,500	136,800	112,800	75,800	58,500
Muskoka Airport	4,837	238,200	149,700	167,200	154,100	139,100	114,800	77,100	59,500
Nakina	6,540	322,000	202,400	226,100	208,400	188,100	155,200	104,300	80,400
Napanee	4,130	203,400	127,800	142,800	131,600	118,800	98,000	65,900	50,800
Newcastle	4,130	203,400	127,800	142,800	131,600	118,800	98,000	65,900	50,800
New Liskeard	5,830	287,100	180,400	201,600	185,800	167,700	138,400	93,000	71,700
Newmarket	4,350	214,200	134,600	150,400	138,600	125,100	103,200	69,400	53,500
Niagara Falls	3,740	184,200	115,700	129,300	119,200	107,600	88,800	59,600	46,000
North Bay	5,318	261,900	164,600	183,900	169,500	153,000	126,200	84,800	65,400
Norwood	4,520	222,600	139,900	156,300	144,000	130,000	107,300	72,100	55,600
Oakville	3,640	179,200	112,600	125,800	116,000	104,700	86,400	58,100	44,800
Orangeville	4,650	229,000	143,900	160,800	148,100	133,800	110,400	74,200	57,200
Orillia	4,610	227,000	142,600	159,400	146,900	132,600	109,400	73,500	56,700
Oshawa	4,130	103,400	126,800	242,800	131,600	118,800	98,000	65,900	50,800
Ottawa	4,673	230,100	144,600	161,600	148,900	134,400	110,900	74,500	57,500
Owen Sound	4,220	207,800	130,600	145,900	134,500	121,400	100,100	67,300	51,900
Pagwa River	6,330	311,700	195,900	218,800	201,700	182,100	150,200	101,000	77,800
Paris	4,030	198,400	124,700	139,300	128,400	115,900	95,600	64,300	49,600
Parkhill	3,980	196,000	123,200	137,600	126,800	114,500	94,500	63,500	48,900
Parry Sound	4,620	227,500	143,000	159,700	147,200	132,900	109,600	73,700	56,800
Pembroke	4,960	244,200	153,500	171,500	158,100	142,700	117,700	79,100	61,000
Pentanguishene	4,580	225,500	141,700	158,300	145,900	131,700	108,700	73,000	56,300
Perth	4,520	222,600	139,900	156,300	144,000	130,000	107,300	72,100	55,600
Petawawa	5,010	246,700	155,000	173,200	159,600	144,100	118,900	79,900	61,600
Peterborough	4,520	222,600	139,900	156,300	144,000	130,000	107,300	72,100	55,600
Petrolia	3,750	184,700	116,000	129,600	119,500	107,900	89,000	59,800	46,100
Picton	4,080	200,900	126,200	141,100	130,000	117,400	96,800	65,100	50,200
Plattsville	4,130	203,400	127,800	142,800	131,600	118,800	98,000	65,900	50,800
Point Alexander	5,180	255,100	160,300	179,100	165,100	149,000	122,900	82,600	63,700
Porcupine	6,220	306,300	192,500	215,000	198,200	178,900	147,600	99,200	76,500
Port Burwell	3,810	187,600	117,900	131,700	121,400	109,600	90,400	60,800	46,900
Port Colborne	3,640	179,200	112,600	125,800	116,000	104,700	86,400	58,100	44,800
Port Credit	3,700	182,200	114,500	127,900	117,900	106,400	87,800	59,000	45,500
Port Dover	3,830	188,600	118,500	132,400	122,000	110,200	90,900	61,100	47,100
Port Elgin	4,240	208,800	131,200	146,600	135,100	122,000	100,600	67,600	52,100
Port Hope	4,190	206,300	129,700	144,900	133,500	120,500	99,400	66,800	51,500
Port Perry	4,410	217,200	136,500	152,500	140,500	126,800	104,700	70,300	54,200
Port Stanley	3,810	187,600	117,900	131,700	121,400	109,600	90,400	60,800	46,900
Prescott	4,350	214,200	134,600	150,400	138,600	125,100	103,200	69,400	53,500
Princeton	4,030	198,400	124,700	139,300	128,400	115,900	95,600	64,300	49,600
Raith	6,060	298,400	187,500	209,500	193,100	174,300	143,800	96,600	74,500

Table A1
(Continued)
AVERAGE SPACE HEATING ENERGY REQUIREMENTS
FOR RESIDENTIAL UNITS IN ONTARIO COMMUNITIES
(MJ/Unit/Year)

Town	Degree Days °C	Single Family Residential Units						Multiple Units	
		L-Shaped	Regular	Split-Level	Two Storey	Semi-Detached	Row	Low Rise	High Rise
Red Lake	6,220	306,300	192,500	215,000	198,200	178,900	147,600	99,200	76,500
Renfrew	4,790	235,900	148,900	65,600	152,600	137,800	113,700	76,400	58,900
Ridgeway	3,590	176,800	111,100	124,100	114,400	103,300	85,200	57,300	44,100
Rockland	4,800	236,400	148,500	166,000	153,000	138,100	113,900	76,600	59,000
St. Catharines	3,550	174,800	109,800	122,700	113,100	102,100	84,200	56,600	43,700
St. Marys	4,130	203,400	127,800	142,800	131,600	118,800	98,000	65,900	50,800
St. Thomas	3,580	176,300	110,800	123,800	114,100	103,000	85,000	57,100	44,000
Sarnia	3,840	189,100	118,800	132,800	122,400	110,500	91,100	61,200	47,200
Sault Ste. Marie	5,180	255,100	160,300	179,100	165,100	149,000	122,900	82,600	63,700
Schriber	6,070	298,900	187,800	209,900	193,400	174,600	144,100	96,800	74,600
Seaforth	4,240	208,800	131,200	146,600	135,100	122,000	100,600	67,600	52,100
Simcoe	3,962	195,100	122,600	137,000	126,200	114,000	94,000	63,200	48,700
Sioux Lookout	6,180	304,300	191,200	213,700	196,900	177,800	146,700	98,600	76,000
Smith Falls	4,520	222,600	139,900	156,300	144,000	130,000	107,300	72,100	55,600
Smithville	3,920	193,000	121,300	135,500	124,900	112,800	93,000	62,500	48,200
Smooth Rock Falls	6,280	309,200	194,300	216,100	200,100	180,600	149,000	100,200	77,200
Southampton	4,520	222,600	139,900	156,300	144,000	130,000	107,300	72,100	55,600
South Porcupine	6,220	306,300	192,500	215,000	198,200	178,900	147,600	99,200	76,500
South River	5,180	255,100	160,300	179,100	165,100	149,000	122,900	82,600	63,700
Stirling	4,340	213,700	134,300	150,000	138,300	124,800	103,000	69,200	53,400
Stratford	4,300	211,700	133,100	148,700	137,000	123,700	102,000	68,600	52,900
Strathroy	3,920	193,000	121,300	135,500	124,900	112,800	93,000	62,500	48,200
Streetsville	4,080	200,900	126,200	141,100	130,000	117,400	96,800	65,100	50,200
Sturgeon Falls	5,180	255,100	160,300	179,100	165,100	149,000	122,900	82,600	63,700
Sudbury	5,447	268,200	168,500	188,300	173,600	156,700	129,300	86,900	67,000
Sundridge	5,120	252,100	158,400	177,000	163,100	147,300	121,500	81,700	63,000
Tavistock	4,190	206,300	129,700	144,900	133,500	120,500	99,400	66,800	51,500
Thamesford	4,030	198,400	124,700	139,300	128,400	115,900	95,600	64,300	49,600
Thedford	3,860	190,100	119,400	133,500	123,000	110,000	91,600	61,600	47,500
Thunder Bay	5,746	282,900	177,800	198,700	183,100	165,300	136,400	91,600	70,700
Tillsonburg	3,920	193,000	121,300	135,500	124,900	112,800	93,000	62,500	48,200
Timagami	5,570	274,300	172,400	192,600	177,500	160,200	132,200	88,800	68,500
Timmins	6,189	304,800	191,500	214,000	197,200	178,000	146,900	98,700	76,100
Toronto	4,082	201,000	126,300	141,100	130,100	117,400	96,900	65,100	50,200
Trenton	4,186	106,100	129,500	144,700	133,400	120,400	99,300	66,800	51,500
Trout Creek	5,230	257,500	161,800	180,800	166,700	150,400	124,100	83,400	64,300
Trout Lake	7,680	378,200	237,600	265,500	244,700	220,990	182,300	122,500	94,400
Uxbridge	4,450	219,100	137,700	153,800	141,800	128,000	105,600	71,000	54,700
Vanier	4,690	230,900	145,100	162,100	149,400	134,900	111,300	74,800	57,700
Vittoria	3,680	181,100	113,900	127,200	117,300	105,900	87,300	58,700	45,300
Walkerton	4,160	204,800	128,700	143,800	132,600	119,700	98,700	66,300	51,200

Table A1
(Continued)
AVERAGE SPACE HEATING ENERGY REQUIREMENTS
FOR RESIDENTIAL UNITS IN ONTARIO COMMUNITIES
(MJ/Unit/Year)

Town	Degree Days °C	Single Family Residential Units						Multiple Units	
		L-Shaped	Regular	Split-Level	Two Storey	Semi-Detached	Row	Low Rise	High Rise
Wallaceburg	3,620	178,300	112,000	125,200	115,400	104,100	85,900	57,700	44,500
Waterloo	4,110	202,400	127,200	142,100	131,000	118,200	97,500	65,500	50,500
Watford	3,810	187,600	117,900	131,700	121,400	109,600	90,400	60,800	46,900
Wawa	5,640	277,700	174,500	195,000	179,700	162,200	133,800	89,900	69,400
Welland	3,640	179,200	112,600	125,800	116,000	104,700	86,400	58,100	44,800
West Lorne	3,750	184,700	116,000	129,600	119,500	107,900	89,000	59,800	46,100
Whitby	4,080	200,900	126,200	141,100	130,000	117,400	96,800	65,100	50,200
White River	6,380	314,200	197,400	220,600	203,300	183,500	151,400	101,700	78,500
Warton	4,412	217,300	136,500	152,500	140,600	126,900	104,700	70,400	54,300
Windsor	3,590	176,800	111,100	124,100	114,400	103,300	85,200	57,300	44,100
Wingham	4,240	208,800	131,200	146,600	135,100	122,000	100,700	67,600	52,100
Woodstock	4,100	201,900	126,900	141,700	130,600	117,900	97,300	65,400	50,400
Wyoming	3,810	187,600	117,900	131,700	121,400	109,600	90,400	60,800	46,900

Source: Degree days obtained from the Ontario Building Code, space heating estimates derived by authors.

A.1 Table A1 Explanatory Notes

In order to calculate the space heating energy requirements of the residential component of the development proposal being evaluated the user must first categorize all residential buildings by type.

Based on the characteristics of each standard building type the average space heating energy coefficients were calculated and adjusted for variations in the average degree days for 218 communities in Ontario.

A.1.1 Residential Building Types

This manual provides a choice of eight residential building types which the user should use to categorize the residential units in the proposed development. The eight building types reflect the type of residential units commonly found in developments today. They are:

A. Single Family Units

- L-shaped One Storey
- Regular One Storey House
- Split Level House
- Two Storey House
- Semi-detached Two Storey House
- Row House

B. Multiple Family Units

- Low Rise Apartment Building Units (walk-up)
- High Rise Apartment Building Units (elevator)

Residential structures that do not fit the standard categories can be analyzed separately, however the user is encouraged to select from the standard building types for an initial estimation of energy consumption. With an appreciation of the methodology and

the level of accuracy inherent in the calculation the user can then obtain the detailed information and characteristics and undertake the more detailed calculations. These procedures are outlined in Section B of the Catalogue.

A.1.2 Single Family Units

The six single family units and their characteristics correspond with CMHC standard residential unit types found in the 1977 CMHC publication The Conservation of Energy in Housing. The basic components of each unit type presented in Table A5 and illustrated in Chapters 1 and 2 will assist the user in identifying how the residential units in the new development under evaluation should be categorized. Based on the characteristics of each unit type the average space heating energy coefficients were calculated and adjusted for variations in the average degree days for 218 communities in Ontario. This information is presented in Table A1. Should the community in which the new development is proposed not be listed in Table A1, the figures for the closest community listed should be used.

A.1.3 Multiple Family Units

The methodology for the calculation of space heating energy consumption used for multiple family units is similar to that developed for single family units. However, the more complex nature of multiple family buildings with respect to heating systems and the fact that heating is often centrally controlled, do not allow for the same degree of accuracy. If the user has detailed characteristics of the multiple family structures proposed then Section B of the Catalogue should be used to obtain a more accurate space heating energy coefficient. Where detailed information is not available the user must choose between two categories of multiple family units, low-rise (walk-up) or high-rise (elevator). Based on the characteristics of these two building types the average space heating energy coefficients were calculated and adjusted for variations in the average degree days for 218 communities in Ontario. This information is presented in Table A1.

The user, where possible, should undertake detailed calculations for multiple family buildings. Sections B.2.2 and B.2.3 of the Catalogue illustrate the basic calculation for a low-rise and high-rise apartment building respectively. The results of these calculations are then adjusted for the degree days of each community in Table A1.

1. Low-rise Apartments

The basic design characteristics of a low-rise apartment are shown below and also discussed in Section B.2.2 of the Catalogue.

Building Size:	20 m x 32 m
Building Height:	11 m
Number of Units:	22
Average Unit Size:	100 m ²

2. High-rise Apartments

The basic design characteristics of a high-rise apartment are shown below and also discussed in Section B.2.3 of the Catalogue.

Building Size:	20 m x 66 m
Building Height:	60 m
Number of Units:	234
Average Unit Size:	100 m ²

TABLE A2
BASE UNIT COMPONENT SIZES
(in m²)

	Exterior		Foundation			Floor	
	Area	Windows	Walls	Walls	Doors	Slab	Roof
"L" Shaped One Storey	164	22	116	116	4	164	164
Regular One Storey	97	13	81	81	4	97	97
Split Level	108	14	119	100	4	87	87
Two Storey	103	13	105	75	4	64	64
Semi-Detached	103	13	90	90	4	51	51
Townhouse	99	10	59	59	4	49	49

Source: CMHC The Conservation of Energy in Housing, Publication
NHA 5149, Ottawa, 1977 (Adjusted)

TABLE A3
FLOOR AREA AND NET HEAT LOAD ADJUSTMENTS

Floor Area Adjustment	"L" Shaped One Storey	Regular One Storey	Split Level	Two Storey	Semi-Detached	Row House
Adjusted Floor Areas in m ²						
- 20%	131	78	86	82	82	79
Base *	164	97	108	103	103	99
+ 20%	197	116	130	124	124	119
+ 50%	246	146	162	155	155	149
Corresponding Net Heat Loads in KJ/°C.Hr.						
- 20%	1048	683	777	701	639	521
Base *	1233	775	865	788	719	594
+ 20%	1435	918	1009	917	845	680
+ 50%	1684	1088	1208	1091	998	869

* Base housing unit size as described in Table A2

A.3 Table A3 Explanatory Notes

The space heating requirements of the six basic houses are calculated using typical insulation standards (Table B1), a heat gain factor of 0.75, and an air exchange rate of 0.75. The changes in space heating requirements are then calculated to account for variations in the basic floor areas of each unit type (-20%, +20%, +50%). The results in Table A3 are expressed in kilo-joules per degree celsius hour.

TABLE A4
INSULATION ADJUSTMENTS
(KJ/°C.Hr)

Floor Area * Adjustment	"L" Shaped One Storey	Regular One Storey	Split Level	Two Storey	Semi- Detached	Row House
Base Area m ²	164	97	108	103	103	99
Increase Roof Insulation from 12 cm to 47 cm (U .28 to .12)						
- 20%	- 59	- 35	- 31	- 23	- 18	- 17
Base	- 73	- 43	- 39	- 29	- 23	- 22
+ 20%	- 88	- 52	- 47	- 34	- 27	- 26
+ 50%	- 110	- 65	- 59	- 43	- 34	- 33
Increase Exterior Wall Insulation from 10 cm to 15 cm and air space (U .48 to .40)						
- 20%	- 21	- 16	- 23	- 21	- 17	- 12
Base	- 23	- 17	- 24	- 22	- 18	- 12
+ 20%	- 25	- 17	- 26	- 23	- 20	- 13
+ 50%	- 26	- 18	- 29	- 25	- 21	- 14
Increase Foundation Wall Insulation with 8 cm polystyrene insulation (U .57 to .47)						
- 20%	- 26	- 20	- 26	- 26	- 22	- 14
Base	- 30	- 21	- 26	- 27	- 23	- 15
+ 20%	- 31	- 22	- 28	- 28	- 24	- 16
+ 50%	- 33	- 23	- 31	- 31	- 26	- 17
Windows: Increase from double glaze to triple glaze (U 3.1 to 2.0)						
- 20%	- 66	- 39	- 42	- 39	- 39	- 30
Base	- 66	- 39	- 42	- 39	- 39	- 30
+ 20%	- 81	- 51	- 51	- 51	- 51	- 30
+ 50%	- 81	- 60	- 60	- 60	- 60	- 54

* Adjustments to basic floor area as shown in Table A3.

TABLE A4 (continued)
INSULATION ADJUSTMENTS

Floor Area * Adjustment	"L" Shaped One Storey	Regular One Storey	Split Level	Two Storey	Semi- Detached	Row House
Base Area m ²	164	97	108	103	103	99
Increase Door Insulation with Solid, Non-warping Doors (U 2.4 to 0.76)						
- 20%	- 18	- 18	- 18	- 18	- 18	- 18
Base	- 18	- 18	- 18	- 18	- 18	- 18
+ 20%	- 27	- 27	- 27	- 27	- 27	- 27
+ 50%	- 36	- 36	- 36	- 36	- 36	- 36
Increase Insulation of all Factors						
- 20%	- 303	- 201	- 225	- 202	- 184	- 150
Base	- 347	- 223	- 244	- 221	- 201	- 163
+ 20%	- 408	- 269	- 289	- 263	- 242	- 188
+ 50%	- 473	- 319	- 246	- 313	- 286	- 249

* Adjustments to basic floor areas as shown in Table A3

A.4 Table A4 Explanatory Notes

The impact of improving insulation standards on space heating requirements is examined using the six basic house types and sizes. Each component of the building envelope is upgraded to the improved standards documented in Table B1, and the results are presented in Table A4. These results are expressed as a change from the base net heat loads in Table A3. They should be added to or subtracted from the net heat load of the corresponding value in Table A3 for the same type and size unit using Table A6.

In all calculations the air exchange rate has been held constant at 0.75. However, as the insulation standards are improved, the heat gain factor is gradually reduced from 0.75 to 0.65. In estimating the impact of improving each of the 5 building envelope components, the heat gain factor is reduced by an increment of 0.02. (i.e., from 0.75 to 0.65) when all 5 components are improved to the higher standard. The only component which is not affected as a result of these improvements is the basement slab. Due to the nature of this incremental adjustment, slight variations $\pm 5\%$ may result when more than one adjustment is made. Combinations other than those provided in Table A4 may be interpolated from the data provided.

TABLE A5
VENTILATION ADJUSTMENTS
(KJ/°C Hr)

Floor Area * Adjustment	"L" Shaped One Storey	Regular One Storey	Split Level	Two Storey	Semi- Detached	Row House
Base Area m ²	164	97	108	103	103	99
Very Low Air Exchange Rate (.30 air changes per hour)						
- 20%	- 172	- 103	- 113	- 107	- 107	- 104
Base	- 215	- 128	- 142	- 136	- 136	- 130
+ 20%	- 257	- 154	- 170	- 162	- 162	- 155
+ 50%	- 322	- 192	- 213	- 203	- 203	- 195
Low Air Exchange Rate (.50 air changes per hour)						
- 20%	- 96	- 57	- 63	- 60	- 60	- 58
Base	- 120	- 71	- 79	- 75	- 75	- 72
+ 20%	- 143	- 86	- 94	- 90	- 90	- 86
+ 50%	- 179	- 107	- 118	- 113	- 113	- 108
High Air Exchange Rate (1.5 air changes per hour)						
- 20%	287	171	189	180	180	173
Base	360	213	237	226	226	217
+ 20%	430	257	283	270	270	259
+ 50%	537	320	355	338	338	325
Very High Air Exchange Rate (2.0 air changes per hour)						
- 20%	479	285	314	300	300	289
Base	600	355	395	377	377	362
+ 20%	716	428	472	450	450	431
+ 50%	896	533	592	563	563	541

* Adjustments to basic floor areas as shown in Table A3

TABLE A6
ADJUSTED SPACE HEATING LOADS

Calculation	Unit Type	L-Shaped One Storey	Regular One Storey	Split Level	Two Storey	Semi Detached	Row House
1. Floor Area Adjustment % (Table A3)							
2. Net Heat Load KJ/°C-Hr. (Table A3)							
Insulation Adjustments KJ/°C-Hr (Table A4)							
3. Roof							
4. Exterior Wall							
5. Foundation Wall							
6. Triple Glaze							
7. Door							
8. Sub Total (Sum 3-7) or							
9. All Factors (Table A4)							
10. Ventilation Adjustment (Table A5)							
11. Adjusted Net Heat Load $2 + (8 \text{ or } 9) + 10$ KJ/°C-Hr							
12. Daily Heat Load $11 \times 24 \text{ hr/day}$							
13. Heating Degree Days (Table A1)							
14. Furnace Efficiency (Table B4)							
15. Annual Heat Load Factor $12 \times 13 \div 14 \div 1000$ MJ/Year							

A.6 Table A6 Explanatory Notes

Where adjustments are required the user should complete Table A6 as directed below to obtain an adjusted space heating energy coefficient which can then be used in the Residential Energy Consumption Worksheet (column 4) for the appropriate unit type.

Line 1 - Floor Area Adjustment

If the area of the residential units in the new development are larger or smaller than the base value (i.e., -20%, +20% or +50%) then the appropriate value is found in Table A3 and entered in Line 1 for those unit types for which adjusted space heating energy coefficients are to be calculated.

Line 2 - Net Heat Load

The net heat load, expressed in KJ/°C-Hour, for the adjusted area of the unit types for which adjusted space heating energy coefficients are to be calculated is taken from the second part of Table A3 and entered under the appropriate unit type in Line 2.

Lines 3 through 7 - Insulation Adjustments

With reference to the appropriate unit type and adjusted area selected in Line 1, identify the value in Table A4 resulting from the insulation adjustment(s) chosen and enter in the appropriate Line (3 to 7) on Table A6.

Line 8 or 9 - Sum of Insulation Adjustments

Line 8 is the sum of all values in Lines 3 through 7 for each unit type. It should be noted that if ALL insulation adjustments are made then the appropriate values from the last section of Table A4 should be entered in Line 9. If this condition exists then Lines 3 through 8 will be blank.

Line 10 - Ventilation Adjustment

The ventilation adjustment for each unit type as adjusted for area, is selected from Table A5 and entered in Line 10.

Line 11 - Adjusted Net Heat Load

The adjusted net heat load expressed in KJ/°C-Hour, is calculated by the sum of Lines 2, 8 or 9 and 10 and the result entered in Line 11.

Line 12 - Daily Heat Load

The adjusted net heat load (Line 10) is multiplied by 24 hours to obtain the daily heat load for a unit type expressed in KJ/°C.

Line 13 - Heating Degree Days

The average heating degree days for the town in which the new development is located can be obtained from Table A1 and is entered in Line 13 of each unit type.

Line 14 - Furnace Efficiency

The efficiency of various types of furnaces can be obtained from Table B4 and is entered in Line 14 for each unit type.

Line 15 - Annual Heat Load Factor

The annual heat load factor is calculated for each unit type by multiplying the daily heat load (Line 12) by the heating degree days (Line 13) and dividing by the furnace efficiency (Line 14) and 1,000. The adjusted heat load factor is expressed in MJ/Year and should be entered opposite the appropriate unit type in Column 4 of Worksheet No.1.

TABLE A7RESIDENTIAL SPACE COOLING ENERGY

	<u>KJ/m²/DD</u>	<u>MJ/m²/year</u> ¹⁾	<u>MJ/unit/year</u> ²⁾
Single:			
Detached	355	95.9	9,600
Attached/Row	284	76.7	7,700
Multiple			
Low Rise	180	48.6	4,900
High Rise	92	24.8	2,500

1) Assuming 270 cooling degree days per year.

2) Assuming 120 m²/unit for single detached, 110 m²/unit for single attached, 100 m²/unit for multiple units.

Main Source: Brookhaven National Laboratory. The Planner's Energy Workbook, New York, 1977.

A.7 Table A7 Explanatory Notes

The degree day concept in cooling is the same as heating, and represents the number of days in a year when the outdoor temperature is one degree celsius above the desired indoor temperature. For example, a five degree celsius difference between the actual outdoor and desired indoor temperature over 24 hours will be measured as 5 cooling degree days. The numbers presented in Table A2 are approximate estimates based on literature sources. A more detailed method to measure cooling energy requirements would have to simulate heat flow characteristics depending on various climatic, design and cooling system conditions. However, given the relatively small share of total energy represented by cooling, a procedure similar to the detailed heat load calculations has not been developed in this manual.

The space cooling energy coefficients in KJ/m²/DD and MJ/m²/Yr. are provided should the user wish to input a modified space cooling coefficient based on different unit sizes or cooling degree days.

TABLE A8
ENERGY CONSUMPTION
IN DOMESTIC HOT WATER HEATING

	<u>MJ/unit/year</u>
Single:	
Detached	24,100
Attached	25,400
Row	17,500
Multiple:	
Low Rise	12,400
High Rise	12,400

Main Source: Informetrica and ERG (1978), Table 21, pp.90.

A.8

Table A8 Explanatory Notes

The main variable in water heating is the level of water consumption which in turn is related to household size and lifestyles. In the past few years, other factors that have affected energy requirements of water heating are improving system efficiencies, and reduced maximum temperature requirements. The average domestic water heating efficiency has traditionally been less than 50% in gas and oil systems (Informetrica and ERG, 1978), but the efficiency of new systems are often above 60%. The effect of reducing temperature rise from 100°F to 70°F has been estimated by Arthur D. Little (1975) to be 30% of energy consumption. The data presented in Table A8 is a range of estimates for different unit types. The basis for these estimates is calculated values modified by the distribution of water heating by fuel type obtained from 1981 new construction statistics. The Market Analysis Department of Ontario Hydro estimates the split in type of water heating in 1981 new construction to be:

	<u>Type of Fuel</u>		
<u>Type of Unit</u>	<u>Gas</u>	<u>Electricity</u>	<u>Other</u>
Single	76	24	less than 1
Apartment	81	19	less than 1

A gross Ontario average figure of 6,000 kwh (19,000 MJ) per year for all types of units is often used by Ontario Hydro.

Additional information is available from the Ontario Ministry of Housing's publication Residential Site Design and Energy Conservation (Figure 18), and Desfor, Miloff & Hass, Urban Form and Energy Consumption, (p.68).

TABLE A9

RESIDENTIAL ENERGY CONSUMPTION
FOR LIGHTING AND HOUSEHOLD APPLIANCES

<u>Type of Use</u>	<u>MJ/unit/year</u>
Single:	
Detached	21,000
Attached/Row	21,000
Multiple Units:	
Low Rise	17,000
High Rise	17,000

Main Source: Informetrica and ERG (1978)

SECTION B

DETAILED SPACE HEATING CALCULATIONS

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B.1 Space Heating Calculations for Individual Buildings**B.1.1 Introduction**

Section B of the Catalogue is only of importance if the user has detailed information about a specific building. This information must include its basic structural characteristics (e.g., wall, roof, window, door area), building volume, location and approximate level of insulation. The result of the detailed space heating calculation for each building type is then entered in the appropriate Line of Column 4 of Worksheet No.1 in lieu of the average value provided in Table A1 of the Catalogue.

The detailed method developed for calculating space heating for individual buildings is based on the principles discussed in Section B.3. The method is outlined below and worked examples are provided to further illustrate the methodology.

B.1.2 Explanation of Detailed Space Heating Calculation

The user must first identify the components of the building envelope and obtain the surface area of each component. For single family dwellings it is suggested that six components are considered:

1. roof
2. exterior walls
3. windows
4. doors
5. basement floor
6. foundation walls.

For multi-dwelling residential and commercial buildings, only the first three of these components should be used.

The U values (metric measure of insulation) of different components, for given construction materials and insulation standards, are documented in Table B1. Based on this data, conductance losses can be estimated. The ventilation losses require the building volume and an estimate of air exchange rates which can be selected from Table B2.

There is no simple method for estimating solar heat gains, which are not only a function of the material properties of the building envelope but also the location and orientation of the building and the shading from surrounding objects. The internal gains are also difficult to determine. Even if they could be estimated, the procedure becomes complicated because their actual contribution to the interior heat balance is a function of the insulation quality of the building envelope and thus is subject to all the heat loss properties discussed in Section B2. The simplified method estimates these gains, both solar and internal, as a proportion of total heat loss through the building envelope. This is based on the Heat Gain Factor which can be selected from Table B3 for different types of buildings.

Once the Heat Gain Factor is applied to the total heat losses, the resulting figure is an estimate of the Net Heat Load per degree hour. This value can be converted to mega-joules per year (MJ/Year) by multiplying by 24 and the selected number of degree days for the particular city from Table A1, and dividing by one thousand. In order to estimate the net energy requirements for space heating, this figure should be multiplied by the furnace efficiency factor which can be selected from Table B4 for the type of furnace proposed.

B.2 Examples of Detailed Space Heating Calculations

B.2.1 Example No.1: Regular Single family one-storey house

Required data:

Building Type:	Regular Single Family Unit
Location:	Toronto
Building components	Walls 91 m² Roof 97 Windows 13 Doors 4 Foundation Wall 81 Basement Slab 97
Building volume:	291 m ³
U values (Table B1) (J/m ² - °Hr x 3600)	Walls 1,728 Roof 1,008 Windows 11,160 Doors 8,640 Foundation 2,052 Basement Slab 1,692
Air exchange rate (Table B2)	0.75
Heat gain factor (Table B3)	0.75
Degree days (Table A1)	4,082
Furnace efficiency (Table B5)	0.60

EXAMPLE NO.1: SINGLE FAMILY HOUSE

Heat Loss by Conduction			
Type of exposed surface	Surface Area m ²	U - value J/m ² - °Hr (from Tab.B1) x 3600	Heat Loss J/°Hr 2 x 3
1. Walls	81	1728	139,968
2. Roof	97	1008	97,776
3. Windows	13	11,160	145,080
4. Doors (SF houses only)	4	8640	34,560
5. Foundation wall	81	2052	166,212
6. Basement slab	97	1692	164,124
Total Conductivity factor (J/°Hr)			747,720 J/°Hr (5)
Heat Loss by Ventilation (or Infiltration)			
Building volume x air changes/hr x 1300 J/m ³ 291 m ³ x 0.75 x 1300 J/m ³			283,725 J/°Hr (6)
Total Heat Loss (5 + 6)			1,031,445 J/°Hr (7)
Heat Gain Factor (Table B3) 0.75 x Total heat loss (7)			773,584 J/°Hr (8)
Heat Load per degree day: (8) x 24 ÷ 1,000			18,566 KJ/°DD (9)
Annual Heat Load: (9) x Degree days (4,082) from Table A1 ÷ 1,000			75,786 MJ/Yr (10)
Furnace Efficiency (from Table B4)			0.60 (11)
Annual space heating energy requirements per building (10 ÷ 11)			126,311 MJ/Yr (12)

B.2.2 EXAMPLE NO.2: LOW RISE APARTMENT BUILDING - 3½ Storeys

Required Data:

Building Type:	Low rise apartment
Location:	Toronto
Building Size:	20 m x 32 m x 11 m
Number of Apartment Units:	22 units
Average Unit size:	100 m ²
Window Area	15% of wall area
Foundation Wall	1.5 m = 156 m ²
Basement Slab	640 m ²
Building Volume 20 x 32 x 12m	7,680 m ³

EXAMPLE NO.2: LOW RISE APARTMENT BUILDING - 3½ Storeys

Heat Loss by Conduction			
Type of exposed surface	Surface Area m ²	U - value J/m ² - °Hr (from Tab.B1) x 3600	Heat Loss J/°Hr 2 x 3
1. Walls	1144	2736	3,129,984
2. Roof	640	1692	1,082,880
3. Windows	171	23,040	3,939,840
4. Doors (SF houses only)	-	-	-
5. Foundation wall	156	2052	320,112
6. Basement slab	640	1692	1,082,880
Total Conductivity factor (J/°Hr)			9,555,696 (5)
Heat Loss by Ventilation (or Infiltration)			
Building volume x air changes/hr x 1300 J/m ³ 7680 m ³ x 0.40 x 1300 J/m ³			3,933,600 J/°Hr (6)
Total Heat Loss (5 + 6)			13,489,296 J/°Hr (7)
Heat Gain Factor (Table B3) 0.75 x Total heat loss (7)			8,768,042 J/°Hr (8)
Heat Load per degree day: (8) x 24 ÷ 1,000			210,433 KJ/°DD (9)
Annual Heat Load: (9) x Degree days (4082) from Table A1 ÷ 1,000			858,988 MJ/Yr (10)
Furnace Efficiency (from Table B4)			0.60 (11)
Annual space heating energy requirements per building (10 ÷ 11)			1,431,647 MJ/Yr (12)
Multiple family residential buildings: space heating energy per unit (22 units) ((12) ÷ number of units per building)			65,074 MJ/unit/Yr (13)

B.2.3. EXAMPLE NO.3: HIGH RISE APARTMENT BUILDING

Required Data:

Building Type:	High rise apartments
Location:	Toronto
Building Size:	20 m x 66 m x 60 m
Number of Apartment Units:	234 units
Average Unit Size:	100 m ²
Window Area:	15% of wall area
Foundation Wall (1 storey)	516 m ²
Basement Slab	1,320 m ²
Building Volume	$20 \times 66 \times 60 \text{ m} = 79,200 \text{ m}^3$

EXAMPLE NO.3: HIGH RISE APARTMENT - 20 Storeys

Heat Loss by Conduction			
Type of exposed surface	Surface Area m ²	U - value J/m ² - °Hr (from Tab.B1) x 3600	Heat Loss J/°Hr 2 x 3
1. Walls	10,320	2736	28,235,520
2. Roof	1320	1692	2,233,440
3. Windows	1548	23,040	35,665,920
4. Doors (SF houses only)	-	-	-
5. Foundation wall	516	2052	1,058,832
6. Basement slab	1320	1692	2,233,440
Total Conductivity factor (J/°Hr)			69,427,152 (5)
Heat Loss by Ventilation (or Infiltration)			
Building volume x air changes/hr x 1300 J/m ³ 79200 m ³ x 0.40 x 1300 J/m ³			41,184,000 J/°Hr (6)
Total Heat Loss (5 + 6)			106,611,152 J/°Hr (7)
Heat Gain Factor (Table B3) 0.65 x Total heat loss (7) 69,427,152 J/°Hr (8)			
Heat Load per degree day: (B) x 24 ÷ 1,000			1,725,534 KJ/°DD (9)
Annual Heat Load: (9) x Degree days (4082) from Table A1 ÷ 1,000			7,043,630 MJ/Yr (10)
Furnace Efficiency (from Table B4)			0.60 (11)
Annual space heating energy requirements per building (10 ÷ 11)			11,739,383 MJ/Yr (12)
Multiple family residential buildings: space heating energy per unit (234 units) ((12) ÷ number of units per building)			50,168 MJ/unit/Yr (13)
Commercial and institutional buildings: Space heating energy per m ² ((12) ÷ floor space in m ²)			MJ/m ² /Yr (14)

TABLE B1

INSULATION STANDARDS OF TYPICAL BUILDINGS

Type of Building	Building Component	Typical Standards		Improved Standards	
		Component Description	U-Value	Component Description	U-Value
Residential Single Family	Roof	Roofing material, 12cm insulation, drywall	0.28	Roofing material, 47 cm insulation, drywall	0.12
	Exterior Walls	Brick, sheathing, 10 cm insulation, drywall	0.48	Brick, sheathing, airspace 15 cm insulation, drywall	0.40
	Foundation Walls	Concrete	0.57	Concrete, 8 cm Polysterene, interior insulation	0.47
	Windows	Double Glaze	3.1	Triple Glaze	2.0
	Doors	Solid Wood	2.4	Insulated, non-warping	0.76
	Basement Slab	Concrete	0.47	Concrete	0.47
Residential Multifamily and Commercial	Roof	Roofing material, 16 cm concrete, gypsum board, 8 cm insulation	0.47	Roofing material, 16 cm concrete, gypsum board, 24 cm insulation	0.20
	Exterior Walls	10 cm face brick, 16 cm concrete block (or 16 cm common brick) furring, gypsum lath, plaster (or drywall), 6 cm insulation (glass fibre).	0.76	16 cm face brick, 16 cm concrete block (or 16 cm common brick) furring, 15 cm insulation (glass fibre), plaster	0.39
	Windows	Single glaze	6.4	Double glaze	3.1

Source: Central Mortgage and Housing Corporation, The Conservation of Energy in Housing, Ottawa 1979 and ASHRAE Standards.

Table B1: Explanatory Notes:

This table suggests improvements to insulation standards for different building components. Should the user wish to use other insulation values then the appropriate U value must be obtained and a detailed space heating calculation for the building undertaken.

TABLE B2AVERAGE AIR EXCHANGE RATES FOR TYPICAL BUILDINGS

(air changes per hour (ACH))

Single Family Detached, Attached and Row	0.75
Multiple Family	0.40
Office Buildings	0.30
Retail - Strip	0.60
- Mall	0.40

Note: The only experimentally obtained figures were available for single-family units (1981 ASHRAE Fundamentals Handbook, Ch.22, Table 2 and Air Quality in the Home EPRI Journal, March 1982). All other values represent estimates.

Table B2 Explanatory Notes:

The air change method for estimating infiltration applies to average construction under average weather conditions. High winds can drastically alter average air exchange rates. ASHRAE has compared the air change method with tracer gas measurements for the same units and determined that the air change method can give estimates within 20% of measurements for average construction under average conditions. As differences of 50% to 100% can occur for extra tight construction or abnormal weather conditions, the air change method should only be considered capable of providing a gross estimate of air exchange rates.

TABLE B3INTERNAL HEAT GAIN FACTORS FOR TYPICAL BUILDINGS

	<u>High</u> (well insulated/ high wild heat)	<u>Low</u> (poorly insulated/ low wild heat)
Single family units	0.65	0.75
Multiple family units	0.55	0.65
Office buildings	0.30	0.60
Schools	0.50	0.60
Retail - Strip	0.40	0.60
- Mall	0.40	0.60

Source: See Explanatory Note 1 below.

Table B3 Explanatory Notes:

- 1) The factors for single family units, and to a lesser extent multiple family units, are fairly reliable estimates based on literature sources. All other values are estimates based on a judgemental assessment of activity type, and comparison of results from other studies (e.g., Arthur D. Little, 1975) with the simplified method developed in Section B of the Catalogue.
- 2) Wild heat is that heat generated by lighting, appliances and people within the building envelope.

TABLE B4TYPICAL SEASONAL FURNACE/SYSTEM EFFICIENCIES

<u>Furnace Type</u>	<u>Efficiency</u>
Electric	1.00
Gas (High Efficiency)	.90
Gas (Regular)	.60
Oil	.60

Source: Informetrica and ERG (1978) p.37.

Table B4 Explanatory Notes:

Slight fluctuations in the efficiency of regular gas and oil furnaces can be expected based on the type of furnace, the operating conditions and regularity of maintenance. Under normal conditions the oil furnace may be slightly more efficient than a regular gas unit.

B.3 Discussion of Approach to Basic Heat Load Calculation

Energy used for heating buildings can accurately be calculated by simulating, in detail, the heat transfer process in and out of the building envelope. Such a simulation procedure must take into account the physical properties of the building envelope, air flow characteristics within the structure, climatic conditions, and internal heat gains. This process will then be simulated on an hourly basis to account for varying temperatures, solar radiation levels and activities within the building throughout the day. Computerized models have been developed to simulate this heat transfer process and calculate the net heat loads of buildings under a wide range of physical, environmental, and climatic conditions.

For the purposes of this Handbook, a simplified heat load estimation procedure has been developed. The method is based on the same heat transfer principles but introducing simplifying assumptions. This method has been experimentally tested for single family houses and given remarkably accurate results. Many experts, however, would seriously question the application of such a simplified method in multi-storey buildings and more so in commercial buildings.

However, in the absence of any other means of estimating the effects of building characteristics (e.g., size, shape, insulation levels, etc.) on space heating requirements, it was concluded that the method developed could also be used for multi-storey buildings, both residential and commercial. When unique designs are being used, the results should always be tested against the average energy coefficients provided in Appendices A and C.

B.4 Theoretical Principles of the Net Heat Load Calculation

The purpose of any heating system is to maintain the indoor air temperature at a desired level by either heating the air directly or using water as a medium. Following one of the most fundamental principles of physics, that heat flows from matter at one temperature to the adjacent matter or space at a lower temperature, heat losses occur, and thus more heat has to be generated to maintain the indoor temperature at the same level. If all these losses could be accounted for, the necessary supply of heat can then be determined.

Heat losses in a building mainly occur by conduction and direct air leakage through the building envelope. Transmission heat loss (T) is defined as "the amount of heat energy conducted through a unit area (from one surface to the other) in a unit time with a unit temperature difference between the two surfaces", and it can be expressed as follows:

$$T = UA$$

where A is the surface area (m²) and U is the insulation value normally expressed in Watts per square metre per degree celsius - but can easily be converted to joules since a joule is one watt per second. The resulting transmission heat loss (T) is the heat energy in watts per degree celsius. If the surface area (A) equals the surface area of the building envelope, then T represents the heat loss for every degree celsius difference between outdoor and indoor temperature. Since the U value is a function of the physical properties of the conductance surface, heat losses are not the same for all components of the building envelope (i.e., windows, walls, ceiling, etc.). The total conductance loss for a building is the sum of losses through all the components of its envelope and can be expressed as follows:

$$T = \sum_i U_i A_i \quad \text{where } i \text{ designates each component of the building envelope.}$$

The other major source of heat loss through the building envelope is the direct leakage (infiltration) of air. When warm air leaks out it is naturally replaced by cold air which has to be heated in order to maintain the desired indoor temperature. It takes 1,300 joules of energy to heat a cubic metre of air by one degree celsius under average Ontario conditions. The volume of air leaking through the envelope is normally expressed as a fraction of the building volume, and this fraction is referred to as the number of air changes per unit of time. The resulting infiltration heat loss (I) for every degree celsius difference can then be expressed as follows:

$$I = 1300 V n$$

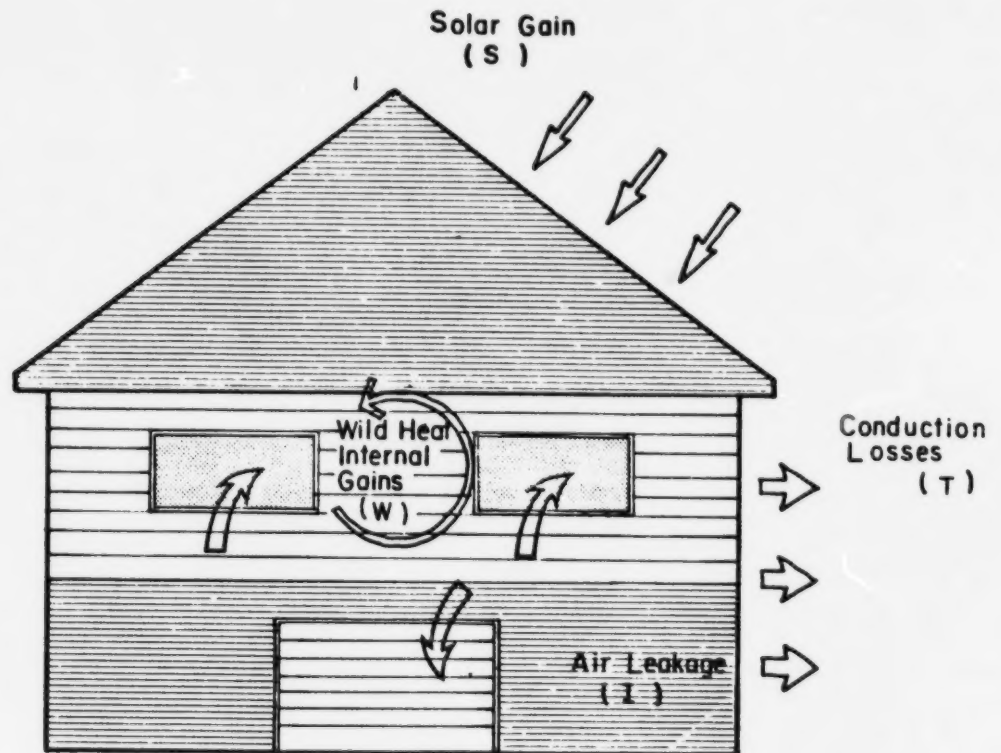
where V is the building volume in cubic metres, and n is the number of air exchanges per hour.

The sum of transmission (T) and infiltration (I) heat losses represents the heat energy that has to be supplied per hour for every degree celsius difference between indoor and outdoor temperature. Part of this energy is generated internally in the buildings by body heat, lights, appliances, and other machinery, and can be referred to as internal or wild-heat gains (W). Passive solar radiation (S) acting through windows or the building envelope in general, is another source of heat energy compensating for some of the heat losses. The net heat load (NHL) in a building can then be expressed as follows:

$$NHL = (T + I) - (W + S)$$

where NHL is in joules per hour per celsius degree. When this is multiplied by 24 hours per day and the heating degree days per year of a specific location, the net annual heat load can be obtained in joules per year.

FIGURE B1

BASIC HEAT LOSS AND GAIN FOR A TYPICAL BUILDING

$$\text{NHL} = (T + I) - (W + S)$$

SECTION C

COMMERCIAL AND INSTITUTIONAL

ENERGY CONSUMPTION

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C.1 Discussion	C-2

TABLES

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C1	Commercial and Industrial Energy Coefficients	C-1
C2	Average Commercial and Institutional Areas	C-4

TABLE C1

COMMERCIAL AND INSTITUTIONAL ENERGY COEFFICIENTS

(Mega-Joules/m²)

	Source	Space Heating	Cooling	Lighting	Fans and Pumps	Water Heating	Auxiliary Miscellaneous	Service Motors Process Power	Total*
Office Buildings	(1)+(2)	363.8	112.0	374.61	53.8	57.0	37.7		1,000
Retail:									
Shopping Mall	(1)	115.2	345.5	693.2	625.4	20.5	43.1		1,900
Strip Retail	(3)	374.6	269.1	693.2	469.3	20.5	43.1		1,900
Service	(4)	374.6	269.1	693.2	469.3	20.5	43.1	720.1	2,600
Food	(4)	374.6	269.1	693.2	469.3	20.5	43.1	1,708.2	3,600
Hotels:									
Small	(4)	403.6	137.8	33.4	110.9	322.9	107.6		1,100
Large	(4)	588.8	164.7	50.6	131.3	322.9	107.6		1,400
Schools	(1)	376.7	42.0	310.0	11.8	107.6	19.4		870
Hospitals	(4)	1,542.5	82.9	376.0	101.2	215.3	505.9		2,800

Sources: (1) A.D. Little (1975)

(2) Informetrica ERG (1978)

(3) Estimated

(4) EMR (1979)

Note: Use figures from shaded area in Column 10 of Worksheet No.2 if average figures as shown in Table C1 are used in Columns 3 through 9.

* These values have been rounded to two significant digits.

C.1 Table C1 Explanatory Notes

The main worksheet for commercial and institutional land use has been designed to offer the user the maximum flexibility in specifying the types of activities and buildings represented in any particular development.

Unlike residential buildings, commercial buildings are very diverse in both their design and operating characteristics. It is therefore difficult to utilize data from existing sources in a consistent manner as studies often start with different assumptions about the design and use of a particular building.

The approach taken in this manual is to provide data for a few basic commercial and institutional categories from a select range of sources to avoid inconsistent assumptions.

Wherever possible A.D. Little (1975) was used as a main source. This study, using a detailed simulation method, examined three types of buildings which are included in our list of commercial/institutional categories: office, retail and school. For offices, the estimates presented in Table C1 were the result of the average of values obtained from A.D. Little (1975) and the Informetrica and ERG (1978) study. Estimates for the remaining categories were obtained from the EMR (1979) study. The estimates in this case, however, were not used directly and instead ratios of energy consumption in these categories to offices were taken and applied to our own estimates of energy consumption for offices. A further difficulty encountered in compiling estimates from the various studies was that land use energy consumption categories were not identical. Adjustments were, therefore, made to make the estimates presented in Table C1 compatible. The strip retail values were estimated by the authors.

As mentioned in Section B of the Catalogue, the simplified heat load calculations developed for this manual can be used in certain cases for commercial and institutional buildings. If the user wishes to assess the impact of variations in building shape and size on space heating energy requirements, the average figures in Table C1 can be replaced by the results of those detailed calculations. It should be emphasized that this is a crude procedure, and could yield results significantly different from the averages provided here.

TABLE C2AVERAGE COMMERCIAL AND INSTITUTIONAL AREAS

<u>Facility</u>	<u>Suggested Area</u>
Primary School (500 students)	1,500 m ²
Secondary School (1,000 students)	3,000 m ²
Community Service Centre	4,500 m ²
Local Fire Station	420 m ²
Public Safety Building (Jail)	2,350 m ²
Tourist Visitors Centre	630 m ²
Senior Citizens High Rise (subsidized) 180 units	9,800 m ²
Senior Citizens High Rise (private) 76, 1-bedroom units	5,500 m ²
Bowling Alley Centre (32 lanes)	2,760 m ²
Health and Racquetball Club	2,600 m ²
Ice Skating Rink Arena	3,350 m ²
Automobile Dealership	1,860 m ²
Banquet Hall Building	2,350 m ²
Bank (local branch)	450 m ²
Hotel (250 rooms)	13,000 m ²
Mixed-Use Hotel-Office-Commercial	43,800 m ²
(315 rooms - 15,000 m ²)	
(6 floors office - 20,000 m ²)	
(commercial - 8,800 m ²)	
Theatre (1,230 seats)	1,700 m ²
General Hospital	100 m ² per bed
Medical Health Centre (230 beds)	13,000 m ²
Regional Animal Centre	800 m ²

Source: Dodge Construction Systems Costs 1982, McGraw-Hill

SECTION D

INDUSTRIAL ENERGY CONSUMPTION

TABLES

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D3	Industrial Energy Coefficients	D-3
D4	Energy Consumption By End Use	D-4

TABLE D1INDUSTRIAL CLASSIFICATIONIndustry categories with
similar energy coefficientsMajor SIC Group Number1)Light Industry

Knitting	5
Clothing	6
Printing and Publishing	10
Electric Products	15
Miscellaneous	18

Medium Industry

Food and Beverage	1
Plastic and Rubber	2
Leather	3
Textiles	4
Wood	7
Furniture and Fixtures	8

Heavy Industry

Paper and Allied Products	9
Primary Metals	11
Metal Fabricating	12
Machinery	13
Transport Equipment	14
Non-Metallic and Mineral Products	16
Chemical	17

- 1) Standard Industrial Classification categories as defined by Statistics Canada.

TABLE D2EMPLOYMENT DENSITY

<u>Type of Industry</u>	<u>Average Employment Density (employees/hectare)</u>
Light	40
Medium	25
Heavy	20

Source: Estimates based on general design criteria

TABLE D3
INDUSTRIAL ENERGY COEFFICIENTS

SIC ** Group	MJ/ * \$ of Output	MJ/ * \$ of value added	MJ/ employee
1	6.1	17.7	414,500
2	7.5	13.8	255,200
3	7.2	15.6	175,100
4	3.9	8.3	125,500
5	3.9	6.6	69,600
6	1.0	1.7	20,000
7	3.8	7.4	138,200
8	3.4	6.8	105,500
9	8.1	17.4	353,300
10	2.2	3.3	62,200
11	10.0	30.3	655,500
12	5.3	9.6	210,000
13	3.3	5.5	124,500
14	3.0	6.4	188,800
15	3.3	5.3	106,500
16	47.4	76.0	1,754,000
17	5.6	9.4	254,200
18	3.5	5.8	115,000
Average Values for General Industry Grouping			
Light Industry	2.8	4.5	74,660
Medium Industry	5.3	11.6	202,300
Heavy Industry	11.8	22.0	505,800

Source: Energy Mines and Resources Canada. Patterns and Levels of Commercial and Industrial Energy Consumption. p.100.

Notes: * The data found in these columns is provided to allow interested users to prepare other estimates of energy use, should the required data on output and value added be available. These estimates could be combined with the employee estimate and the average energy use value may be a more accurate estimate.

** For names of SIC Groups see Table D1.

TABLE D4
ENERGY CONSUMPTION BY END-USE

<u>Major Groups</u>	<u>Process</u>	<u>Space Heating</u>	<u>Lighting</u>	<u>Make-up Air</u>	<u>Motors Turbines</u>	<u>Transportation</u>	<u>Total</u>
1. Food & Beverage	56%	7%	2%	12%	12%	10%	100%
2. Plastic & Rubber	60	4	6	12	15	3	100
3. Leather	44	25	5	20	5	1	100
4. Textiles	49	11	4	21	12	2	100
5. Knitting	12	23	6	44	14	2	100
6. Clothing	8	32	12	18	23	7	100
7. Wood	18	14	4	19	13	32	100
8. Furniture & Fixtures	25	11	7	39	9	8	100
9. Paper and Allied	64	4	1	7	21	3	100
10. Printing and Publishing	8	16	14	42	10	10	100
11. Primary Metals	64	5	1	6	23	2	100
12. Metal Fabricating	24	12	4	44	10	6	100
13. Machinery	36	16	3	26	16	3	100
14. Transportation Equipment	32	17	3	33	13	2	100
15. Electrical Products	22	15	11	38	11	3	100
16. Non-Metallic Mineral Products	85	3	1	4	3	4	100
17. Chemicals & Chemical Products	57	3	1	6	30	4	100
18. Miscellaneous Manufacturing	21	28	9	29	7	5	100

Source: Energy Mines and Resources Canada, (1979)

Note: The Total Energy consumption from Column 9 on Worksheet 3B would be assumed to be 100% and the appropriate consumptions for each end use in this table would be calculated using the percentages shown.

SECTION E

TRANSPORTATION ENERGY DATA

TABLES

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FIGURES

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TABLE E1TRIP PRODUCTION RATES

Dwelling Unit Type	Number of Person Trips per Unit		No. of Person Trips per Unit Per Avg. Weekday	
	Per Avg. Weekday	Per Year	Waterloo 1976	York 1980
Single Family Detached	10.0	3,588	9.0	7.65
Single-Family Attached	7.9	2,912	7.6	7.65
Low-Rise Apartment	5.4	1,664	6.7	4.40
High-Rise Apartment	3.7	1,144	4.7	4.40

Sources:

Institute of Transportation Engineers, Trip Generation, 2nd Edition.
 Sosslan et al., N.C.H.R.P. Report 187

Misc. Ontario transportation studies.

E.1 Table E1 Explanatory Notes

The numbers presented in the left half of this table are essentially those presented by the ITE Trip Generation handbook. In the ITE handbook, these are presented as vehicle-trips, not person-trips; that is, auto occupancy and modal split rates have already been factored in Ontario experience, however, seems to exhibit person-trip rates of approximately these magnitudes (e.g., see Region of Waterloo, 1976 and Region of York, 1980), and hence they are presented as such here.

Use Values in shaded area in Column 2 of Worksheet No.4.

TABLE E2
TYPICAL TRIP ATTRACTION RATES
 (Per Square Metre of Floorspace)

Land Use Activity	Typical Number of Person-Trips per Square Metre of Floorspace	
	Per Average Weekday	Per Year
Industrial - General	0.059	18
- Light	0.059	17
- Manufacturing	0.043	11
- Heavy	0.016	4
- Industrial Park	0.078	25
Office: - General	0.13	36
- Medical	0.75	215
- Government	0.74	193
- Civic Centre	0.27	70
- Office Park	0.23	60
Institutional: - Hospitals	0.18	60
- Schools	See Table E2A	
- Library	0.45	137

Sources:

Institute of Transportation Engineers, Trip Generation, 2nd Edition.
 Sosskin et al., N.C.H.R.P. Report 187.
 Miscellaneous Ontario transportation studies.

E.2 Table E2 Explanatory Notes

The person-trip data shown in this table are based on the vehicle-trip data presented in the ITE handbook and N.C.H.R.P. 187, converted to person-trips based on the auto occupancy and modal split data presented in N.C.H.R.P. 187.

Although Worksheet 4 computes trip attraction rates on the basis of trips per unit floorspace, these rates are also available on a per employee basis. Table E.2A presents the comparable trip attraction rates per employee from the same data sources. As noted on Table E2, school trip rates are only available on this basis.

Use values in shaded area in Column 10 of Worksheet No.4.

TABLE E2A

OTHER TYPICAL TRIP ATTRACTION RATES

Land Use Activity	Typical No. of Person-Trips	
	Per Average Weekday	Per Year
Industrial: (Person-Trips/employee)		
- General	3.00	890
- Light	3.20	870
- Manufacturing	2.01	640
- Heavy	0.82	215
- Industrial Park	3.86	1,240
Office: (Person-Trips/employee)		
- General	3.50	950
- Medical	25.00	7,210
- Government	12.00	3,140
- Civic Centre	6.10	1,600
- Office Park	3.30	1,250
Institutional: (Person-Trips/bed)		
- Hospitals	6.10	1,970
- Nursing Home	2.70	870
Schools: (Person-Trips/Student)		
- Elementary	1.00	260
- Secondary	1.40	380
- Community College	1.50	400
- University	2.50	650
Hotels & Motels: (Person/Trips/Room)		
- Hotels	10.5	3,610
- Motels	10.2	3,500

Sources:

Institute of Transportation Engineers, Trip Generation, 2nd Edition.

Sosskin et al., N.C.H.R.P. Report 187.

Miscellaneous Ontario transportation studies.

E.2A Table E2A Explanatory Notes

Use values in shaded area in Column 10 of Worksheet No.4.

TABLE E3
TYPICAL RETAIL TRIP ATTRACTION RATES

Centre Size Gross Leaseable Area (see notes)	Typical Number of Person-Trips per Square Metre of Floorspace	
	Per Average Weekday	per Year
1,000	1.740	570
2,000	1.340	440
3,000	1.150	380
4,000	1.040	340
5,000	0.953	320
6,000	0.891	290
7,000	0.841	280
8,000	0.800	260
9,000	0.766	250
10,000	0.737	240
20,000	0.569	200
30,000	0.490	170
40,000	0.440	150
50,000	0.405	130
60,000	0.378	120
70,000	0.357	115
80,000	0.340	110
90,000	0.325	110
100,000	0.313	100
120,000	0.292	100
140,000	0.275	90
160,000	0.262	90
180,000	0.251	80
200,000	0.242	80

Source: Institute of Transportation Engineers, Trip Generation - An Informational Report.

E.3 Table E3 Explanatory Notes:

To compute trip rates for centres with floorspaces lying between the tabulated values, linearly interpolate between these values.

If gross floor area is known, divide this value by 1.25 for shopping centres or 1.05 for strip retail prior to entering Table E3.

Use values in shaded area in Column 10 of Worksheet No.4.

TABLE E4TYPICAL PERSONS PER DWELLING UNIT

<u>Dwelling Unit Type</u>	<u>Persons Per Dwelling Unit</u>	
	<u>Low</u>	<u>High</u>
Single Family Detached	3.2	3.8
Single Family Attached	3.2	3.8
Townhouses	3.2	3.8
Low-Rise Apartment	2.0	2.8
High-Rise Apartment	2.0	2.8

Source: Various Ontario planning studies and sewer design criteria.

TABLE E5WORK TRIP LENGTH DATA, SELECTED ONTARIO CITIES, 1971

Census Area	Population	Total Movement (kms)	Kms Per Capita	Mean Trip Length (kms)
1 Guelph	62,660	77,933	1.24	3.9
2 Peterborough	63,530	73,436	1.16	3.6
3 Sarnia	78,945	154,472	1.96	6.5
4 Brantford	80,285	106,458	1.33	4.4
5 Sault Ste. Marie	81,270	123,695	1.52	5.0
6 Kingston	85,875	147,251	1.71	5.5
7 Thunder Bay	112,095	205,331	1.83	6.2
8 Oshawa	120,320	151,884	1.26	4.5
9 Sudbury	155,425	401,068	2.58	8.8
10 Kitchener	226,850	421,683	1.86	5.2
11 Windsor	258,645	595,784	2.30	8.0
12 London	286,010	680,267	2.38	7.0
13 St. Catharines	303,430	670,235	2.21	7.3
14 Hamilton	498,525	1,278,598	2.56	8.4
15 Ottawa	602,510	1,817,155	3.02	8.3
16 Toronto	2,628,045	10,332,392	3.93	10.8

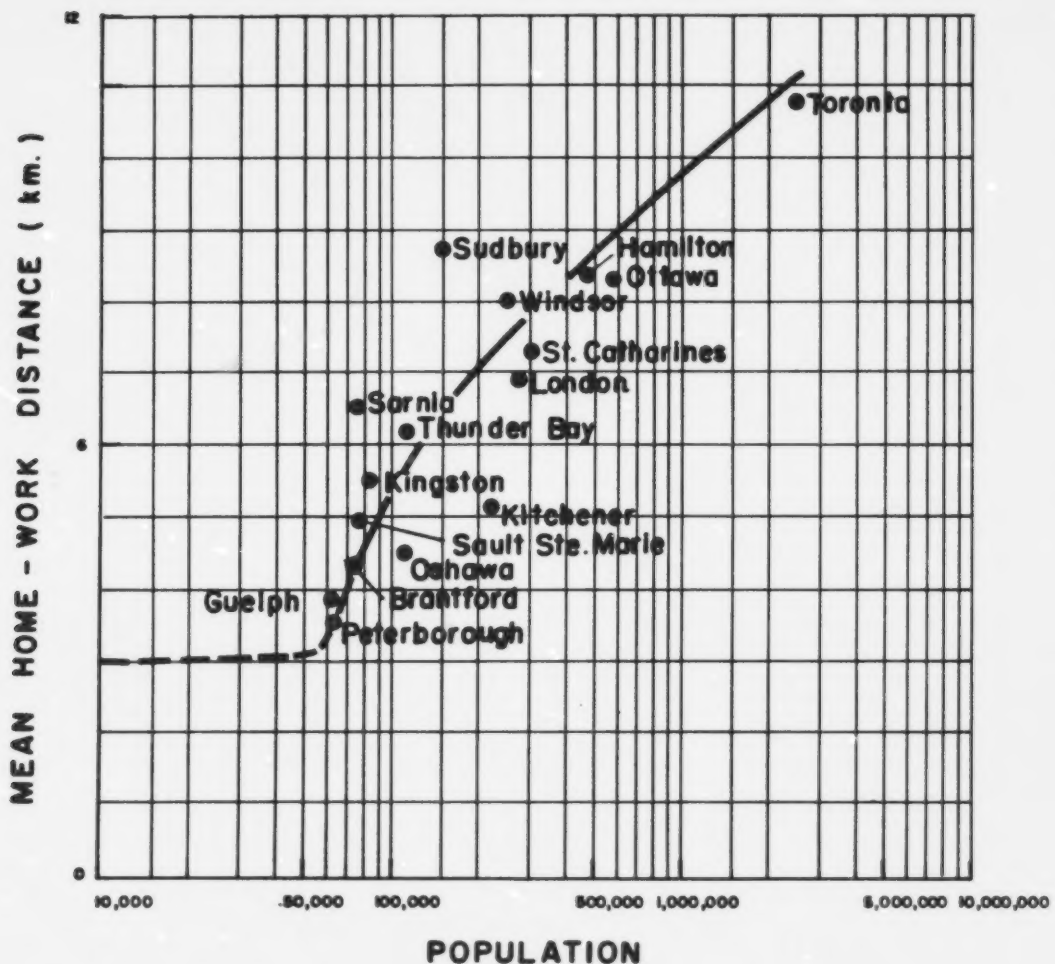
Source: Hutchinson and Smith, 1979.

E.5 Table E5 Explanatory Notes:

The data shown in Figure E1 and Table E5 are for home-to-work trips. Average trip lengths for other trip types typically $\pm 10\%$ of the work trip value. Thus, it is suggested that the work trip average trip length be used as an estimate for the all purpose average trip length.

FIGURE E1

AVERAGE WORK TRIP LENGTHS, ONTARIO CITIES, 1971



Source: Hutchinson and Smith, The Use of Census Journey to Work Data in Ontario Municipalities, Ontario, 1979.

E.5A

Figure E1 Explanatory Notes:

No trip length data is available for towns with a population less than 50,000 on an aggregate basis. It is recommended that an average work trip of 3.0 kilometres be used. Where available local data should be used. An alternative method for estimating average trip length is explained in the notes to Table E6.

TABLE E6

SPATIAL CHARACTERISTICS OF ONTARIO CITIES

Census Area	Spatial Structure			Employment		Households	
	Concentric	Semi Circular	Component Cities	Concentrated	Dispersed	In Balance With Jobs	Away from Job Centres
Guelph	✓				✓	✓	
Peterborough	✓				✓	✓	
Sarnia		✓		✓			✓
Brantford	✓				✓	✓	
Sault Ste. Marie		✓		✓			✓
Kingston		✓			✓		✓
Thunder Bay		✓	✓		✓	✓	
Oshawa	✓			✓		✓	
Sudbury	✓			✓			✓
Kitchener	✓		✓		✓	✓	
Windsor		✓		✓		✓	
London	✓				✓	✓	
St. Catharines	✓		✓		✓	✓	
Hamilton		✓	✓	✓			✓
Ottawa	✓		✓	✓		✓	
Toronto		✓	✓	✓			✓

Source: Hutchinson and Smith, 1979.

E.6

Table E6 Explanatory Notes:Estimating Average Trip Lengths

If the subject municipality is not within one of the regions listed in Table E5, the regional population should be obtained and with reference to Figure E1 a first estimate of average trips length can be made. Regions of less than 50,000 population should use 3.0 km as an estimate.

Should the subject municipality have unusual spatial characteristics then the average trip length may be affected. Table E6 provides spatial characteristics for a number of Ontario municipalities to which the subject municipality can be compared in order to select a similar community, and thus an average trip length which best fits local conditions. The following spatial characteristics are considered.

Spatial Structure:

- | | |
|------------------|--|
| Concentric | - development has expanded in rings in an approximately circular form (i.e., London) |
| Semi-Circular | - impeded by a natural feature such as a lake (i.e., Toronto) |
| Component Cities | - independent urban areas have merged (i.e., Kitchener-Waterloo) |

Employment:

- | | |
|--------------|---|
| Concentrated | - Strong employment centre dominates (i.e., Hamilton) |
| Dispersed | - Dispersed job locations (i.e., Kingston) |

Households:

- | | |
|-----------------------|--|
| In balance | - Job locations dispersed through residential areas (i.e., Kitchener) |
| Away from Job Centres | - Major job locations are same distance from residential area (i.e., Sarnia) |

Use of Table E6 will assist the user to choose an appropriate average trip length from Figure E1 and Table E5. For example, a region with a concentrated employment centre located some distance out of the built-up area might raise the average work-trip length from the normal position on the curve in a manner similar to Sarnia or Sudbury.

TABLE E7

TYPICAL TRANSIT ENERGY CONSUMPTION DATA

Mode	Vehicle Energy Intensity		Load Factor	Seating Capacity	Energy Intensity MJ/Pass-Km
	L/km	MJ/Veh-Km			
Urban Bus	0.52	20.1	0.50	40	1.00
Commuter Bus *	0.47	18.1	0.75	45	0.54

Source: Wilbur Smith and Associates Metropolitan Toronto Area Transportation Energy Study, Summary Report, 1980

E.7 Table E7 Explanatory Notes:

The conversion of Litres to mega-joules (MS) assumes 38.66 mega-joules per litre of diesel fuel.

The load factors are assumed. Local data may be substituted and the mega-joules per passenger-kilometre recalculated according to the formula:

$$\left(\begin{array}{c} \text{Intensity in} \\ \text{MJ/Pass-Km} \end{array} \right) = \frac{\left(\begin{array}{c} \text{Intensity in MJ/Veh-Km} \end{array} \right)}{\left(\begin{array}{c} \text{Seating Capacity} \end{array} \right) \times \left(\begin{array}{c} \text{Load Factor} \end{array} \right)}$$

Use values in shaded area in Line 21 of Worksheet No.4.

* The commuter bus should only be assumed when the transit system consists of coach-type vehicles operating mainly upon highways.

TABLE E.8TYPICAL AUTO OCCUPANCY RATES

Location of Study	Date	Persons per Vehicle		Ratio of All/Work
		Work Trips	All Trips	
Toronto-Hamilton-Oshawa	1964	1.22	1.38	1.13
	1976	1.22	1.38	1.13
Kitchener-Waterloo	1976	1.21	1.33	1.10
Typical U.S.			1.50	1.11
Recommended Value		1.22	1.35*	1.11

Source: Miscellaneous Ontario planning studies.
 Sosslau et al., N.C.H.R.P. Report 187.

E.8 Table E8 Explanatory Notes:

The ratio of auto occupancy for all trips to auto occupancy for work trips is given because: 1) it appears surprisingly constant across studies; and 2) work trip data are often available when all-purpose data are not. Thus if good quality local work trip auto occupancy rates are available, the user may wish to multiply these rates by 1.11 to generate all-purpose rates, rather than use the data shown in this table.

* Use this value in Line 23 of Worksheet No.4.

TABLE E9TYPICAL AUTO ENERGY CONSUMPTION DATA

Ontario Fleet Average Energy Consumption (1979)	14.1 litres/100 km =	4.9 MJ/Veh-km
Typical Cold Start-Trip Length Consumption Ratio		1.3
Net Average Energy Consumption	4.9 x 1.3 =	6.4 MJ/Veh-km

Source: Transport Canada, "Passenger Car Fuel Consumption Survey", May 1980.

E.9 Table E9 Explanatory Notes:

Urban auto fuel consumption is highly dependent upon cold start and trip length effects. This consumption ratio adjusts the fleet average (which is based on all trips, not just urban ones) to account for typical cold start temperatures and trip length. Typical values used in this table correspond to a 10°C cold start and a 9 kilometre trip.

The conversion of litres to mega-joules assumes 34.84 mega-joules per litre of gasoline.

Use value in shaded area in Line 24 of Worksheet No.4.

TABLE E10
TRANSIT MODAL SPLIT DATA

Municipality	Service Population	Transit Trips Per Capita	Transit Modal Split %
Town of Ajax	22,427	10.0	1.3
City of Barrie	39,000	24.3	3.1
City of Belleville	35,000	30.1	3.9
City of Brampton	140,649	25.9	3.3
City of Brantford	83,000	28.0	3.6
City of Burlington	105,000	24.2	3.1
City of Cambridge	74,000	22.9	3.0
Town of Cobalt and Area	13,913	15.7	2.1
Town of Cobourg	11,222	7.3	1.0
Town of Fort Frances	9,500	5.7	0.8
City of Guelph	73,165	47.2	5.9
Region of Hamilton-Wentworth	376,074	76.2	9.2
Town of Kenora and Area	20,000	N/A	N/A
City of Kingston	65,000	44.3	5.6
Township of Kingston	25,000	9.4	1.2
Town of Kirkland Lake	12,047	18.0	2.4
Cities of Kitchener-Waterloo	192,428	43.6	5.5
City of London	258,000	61.2	7.6
Town of Markham	65,063	17.7	2.3
Town of Midland	12,000	9.7	1.3
Town of Milton	20,500	5.9	0.8
City of Mississauga	290,000	36.5	4.7
Town of Newmarket	25,000	10.3	1.4
City of Niagara Falls	70,775	20.6	2.7
City of North Bay	50,000	46.9	5.9
Town of Oakville	70,000	28.3	3.6
City of Orillia	24,000	22.4	2.9
City of Oshawa	114,000	28.6	3.7
Region of Ottawa-Carleton	486,600	152.5	16.9

TABLE E10
(continued)
TRANSIT MODAL SPLIT DATA

Municipality	Service Population	Transit Trips Per Capita	Transit Modal Split %
City of Owen Sound	19,637	17.0	2.2
City of Peterborough	60,000	44.8	5.6
Town of Pickering	28,000	15.5	2.0
Town of Port Hope	10,054	8.6	1.1
Town of Richmond Hill	28,000	10.4	1.4
City of Sarnia and Area	53,000	26.9	3.5
City of Sault Ste. Marie	81,000	40.0	5.1
City of St. Catharines) City of Thorold)	138,857	37.7	4.8
City of Stratford	26,500	28.9	3.7
City of Sudbury) Town of Nickel Centre)	92,000	43.4	5.5
City of Timmins	44,513	N/A	N/A
Metropolitan Toronto	2,113,438	174.8	18.9
Town of Vaughan	17,300	33.8	4.3
City of Welland	45,485	15.7	2.1
Town of Whitby	32,000	1.9	0.3
City of Windsor and Area	196,000	38.1	4.8
City of Woodstock	26,500	20.0	2.6

Source: Ontario Urban Transit Fact Book, 1980.

E.10

Table E10 Explanatory Notes:

If the subject municipality has no transit service, assume a transit modal split of 0.

If the subject municipality in Ontario is just initiating a transit service, choose a city of similar population and estimate a modal split somewhat below the figure found in Table E10.

The transit split was estimated using data on transit passenger trips per capita for each transit system in Ontario (Source: Ontario Urban Transit System Fact Book).

$$a) \quad \text{Transit Modal Split} = \frac{\text{Total Transit Passenger Trips}}{\text{Total Person Trips}}$$

$$b) \quad \begin{aligned} \text{Total Transit Passenger Trips} &= \text{Transit Trips/Capita} \times \text{Population} \\ &= T \times \text{POP} \end{aligned}$$

Where T = Transit Trips per capita
POP = regional population

$$c) \quad \text{Total Person Trips} = (\text{Total Transit Passenger Trips}) + (\text{Total Automobile Passenger Trips})$$

Total Automobile Passenger Trips can be estimated by:
(Auto trips per capita) $\times$ POP $\times$ Vehicle Occupancy.

Auto Trips per capita per average weekday is estimated to be 1.85 from several Ontario Studies and vehicle occupancy is estimated at 1.35 in Table E8 of this report. Thus:

$$\text{Total Auto Passenger Trips} = 1.85 \times \text{POP} \times 300 \text{ avg. days/year} \times \text{persons/Auto.}$$

$$\text{Per Year} = 749.25 \times \text{POP} \quad \text{Say } 750 \times \text{POP.}$$

$$\text{Thus Total Person-Trips/year} = (T \times \text{POP}) + (750 \times \text{POP}).$$

Substituting back into formula a):

$$\begin{aligned} \text{Transit Modal Split} &= \frac{T \times \text{POP}}{(T \times \text{POP}) + (750 \times \text{POP})} \\ &= \frac{T}{T + 750} \end{aligned}$$

SECTION F

CONSTRUCTION ENERGY CONSUMPTION

CONTENTS

TABLES

<u>Table No.</u>		<u>Page</u>
F1	Energy For Construction of New Buildings	F-1
F2	Estimated Project Life Spans	F-2
F3	Total Embodied Energy for Site Development	F-3

TABLE F1ENERGY FOR CONSTRUCTION OF NEW BUILDINGS

Building Type	Total Embodied and Direct Energy
	MJ/m ²
Residential	
Single Family	8.1
Two-Four Family	7.2
High Rise	8.5
Commercial	
Office	18.9
Retail	10.9
Educational	15.9
Hospitals	19.8
Industrial	11.2

After Stein et. al. (1980)

F.1 Table F1 Explanatory Notes:

Construction of new buildings and services (see Table F3) includes both the direct energy expended in construction and the energy embodied in the construction materials. This is the energy required to grow, cut and deliver wood or produce manufactured goods used in the construction of buildings.

TABLE F2ESTIMATED PROJECT LIFE SPANS

Type of Building or Facility	Project Life in Years
Residential (all types)	50
Commercial	
Office	50
Retail	30
Institutional	50
Industrial	20
Roads	25
Piped Services	100

Source: Estimates by author.

F.2 Table F2 Explanatory Notes:

Estimated life for both buildings and services based on discussion with engineers and architects on the useable and economic life expectancy of different land use types and services.

TABLE F3ENERGY FOR DEVELOPMENT OF SITE SERVICES

	MJ/metre
Roads	3.0
Water	1.6
Sanitary Sewers	1.3
Drainage:	
Piping	1.4
Ditching	0.01
Walkways	0.23
Contingencies	1.1

After Cubukgil and Waterhouse (1980)

F.3

Table F3 Explanatory Notes:

Roads include energy required for driveways.

An assumption is made that storm and sanitary sewers operate on a gravity flow basis. Should pumping stations be required, then the construction energy costs must be added into the analysis. No general figures are provided because they vary widely.

As all site services except roads have a life span of 100, a single factor of 5.64 can be used if length is the same for all services. Enter this value in blank line at bottom of Column 10 on Worksheet No.5.

SECTION G

OPERATION OF SERVICE ENERGY CONSUMPTION

CONTENTS

TABLES

<u>Table No.</u>		<u>Page</u>
G1	Solid Waste Disposal Quantities per Year	G-1
G2	Water Treatment Quantities per Year	G-2
G3	Sewage Generation Quantities per Year	G-3
G4	Energy Rates for Services	G-4
G5	Average Annual Service Energy Factors	G-5

TABLE G1SOLID WASTE GENERATED PER YEAR

Residential:

Single Family	1100 kg/Unit
Multi-Family	1100 kg/Unit

Commercial:

Offices	18 kg/m ²
Retail	150 kg/m ²

Educational¹⁾

210,000 kg/school

Hospital²⁾

660,000 kg/hospital

Industrial Warehouses

3,000 kg/m²

Adapted from Peter Middleton and Associates Material and Energy Conservation Benefits of Resource Recovery Through Source Separation, (1980)

1) assumes 1,000 students

2) assumes 500 beds

TABLE G2WATER TREATMENT QUANTITIES PER YEAR

Residential:	
Single Family	570,000 l/unit
Multi-Family	410,000 l/unit
Commercial:	
Offices	1,800 l/m ²
Retail	1,800 l/m ²
Educational ¹⁾	36,000,000 l/school
Hospital ²⁾	750,000,000 l/hospital
Industrial:	
Light	13,000,000 l/hectare
Heavy	20,000,000 l/hectare

After Ministry Of the Environment Guidelines for the Design of Water Distribution Systems, (1979)

- 1) assumes 1,000 students per school
- 2) assumes 500 beds per hospital

TABLE G3SEWAGE GENERATION QUANTITIES PER YEAR

Residential:	
Single Family	450,000 l/unit
Multiple Family	320,000 l/unit
Commercial:	
Offices	1,800 l/m ²
Retail	1,800 l/m ²
Educational ¹⁾	51,000,000 l/school
Hospitals ²⁾	270,000,000 l/hospital
Industrial:	
Light	13,000,000 l/hectare
Heavy	20,000,000 l/hectare

After Ministry Of the Environment Guidelines for the Design of Water Distribution Systems, (1979)

- 1) Assumes 1,000 students per school
- 2) Assumes 500 beds per hospital

G.3 Table G3 Explanatory Notes:

Facilities such as sewage pumping stations vary significantly in response to local conditions and are therefore not included in these energy calculations. If the proposed development requires these facilities the user should obtain estimates of both the building and operating energy consumption values from a qualified design engineer.

TABLE G4ENERGY RATES FOR SERVICES

Sanitary Sewerage ¹⁾	.0016 MJ/ℓ
Water Treatment ²⁾	.0016 MJ/ℓ
Solid Waste Collection & Disposal ³⁾	.306 MJ/kg

- 1) Estimation by authors
- 2) Ministry Of the Environment (1977)
- 3) Peter Middleton and Associates (1980)

G.4 Table G4 Explanatory Notes:

This table provides crude energy rates for sanitary sewage treatment, water treatment and pressurization and solid waste collection and disposal. These numbers should be replaced with local figures wherever possible and updated on a regular basis.

TABLE G5

AVERAGE ANNUAL SERVICE ENERGY FACTORS

1	2	3	4	5	6	7	8
Land Use	Water Treatment Quantities	Water Energy Rates	Sewage Generation Quantities	Sewage Energy Rates	Solid Waste Disposal Quantities	Solid Waste Energy Rates	Service Energy Factor ³⁾
Source	F4	F6	F5	F6	F3	F6	(2x3)+(4x5)+(6x7)
Residential							
Single Family	570,000	.0016	450,000	.0016	1,100	.306	2,000 MJ/unit
Multi-Family	410,000	.0016	320,000	.0016	1,100	.306	1,500 MJ/unit
Commercial							
Offices	1,800	.0016	1,800	.0016	18	.306	11 MJ/m ²
Retail	1,800	.0016	1,800	.0016	150	.306	52 MJ/m ²
Educational ¹⁾	36,000,000	.0016	51,000,000	.0016	210,000	.306	200,000 MJ/school
Hospital ²⁾	750,000,000	.0016	270,000,000	.0016	660,000	.306	1,800,000 MJ/hosp.
Industrial							
Light	13,000,000	.0016	13,000,000	.0016	43,000	.306	55,000 MJ/ha
Heavy	20,000,000	.0016	20,000,000	.0016	43,000	.306	77,000 MJ/ha

1) assumes 1,000 students

2) assumes 500 beds

3) values rounded to two significant digits

G.5 Table G5 Explanatory Notes:

To simplify the calculation required in Worksheet No.6, the average values suggested in Tables G1, G2, G3 and G4 have been combined in Table G5 to produce one Basic Service Energy factor for each of the standard land use types. PLEASE NOTE that if the suggested values in Tables G1, G2, G3 and G4 are replaced then Table G5 must be modified accordingly.

Use value in shaded area in Column 3 of Worksheet No.6.

Blank
Work Sheets

WORKSHEET NO. 1

RESIDENTIAL ENERGY CONSUMPTION

NO.

1 Unit Type	Plan Data		Energy Coefficients (MJ/unit/year)				8 Total of Energy Coefficients (MJ/unit/year)	9 Annual Energy (GJ)
	2 Number of Units	3 Gross Floor Space (m ²)	4 Space Heating	5 Space Cooling	6 Water Heating	7 Lighting and Appliances		
Source	User	User	Table A1	Table A7	Table A8	Table A9	4+5+6+7	2XB+1000

SFLS			+	+	+		
SFR			+	+	+		
SFSL			+	+	+		
SFTS			+	+	+		
SD			+	+	+		
RH			+	+	+		
OTHER			+	+	+		
			+	+	+		
			+	+	+		
			+	+	+		

ALR			+	+	+		
AHR			+	+	+		
OTHER			+	+	+		
			+	+	+		
			+	+	+		
			+	+	+		
			+	+	+		
			+	+	+		
Total Units		11					

SFLS - Single Family L-Shaped
 SFR - Single Family Regular
 SFSL - Single Family Split Level
 SFTS - Single Family Two Storey
 SD - Semi-detached
 RH - Row House
 ALR - Apartments Low Rise
 AHR - Apartments High Rise

10

Total Annual Residential Energy Consumption =
(sum of items in Column 9) (GJ/Year)

Enter in Column 3 of Worksheet No. 7

12

Residential Energy Consumption Indicator =
10 + 11 GJ/unit/year

Enter in Column 6 of Worksheet No. 7

TABLE A6
ADJUSTED SPACE HEATING LOADS

Calculation \ Unit Type	L-Shaped One Storey	Regular One Storey	Split Level	Two Storey	Semi Detached	Row House
1. Floor Area Adjustment % (Table A3)						
2. Net Heat Load KJ/°C-Hr. (Table A3)						
Insulation Adjustments KJ/°C-Hr (Table A4)						
3. Roof						
4. Exterior Wall						
5. Foundation Wall						
6. Triple Glaze						
7. Door						
8. Sub Total (Sum 3-7) or						
9. All Factors (Table A4)						
10. Ventilation Adjustment (Table A5)						
11. Adjusted Net Heat Load $2 + (8 \text{ or } 9) + 10$ KJ/°C-Hr						
12. Daily Heat Load $11 \times 24 \text{ hr/day}$						
13. Heating Degree Days (Table A1)						
14. Furnace Efficiency (Table B4)						
15. Annual Heat Load Factor $12 \times 13 \div 14 \div 1000$ MJ/Year						

WORKSHEET NO. 2

COMMERCIAL AND INSTITUTIONAL ENERGY CONSUMPTION

NO.

1 Land Use Type	2 Gross Floor Space (m ²)	Energy Coefficients (MJ/m ² /Year)						9 Process Power	10 Total of Energy Coeffi cient	11 Annual Energy (GJ)
		3 Space Heating	4 Space Cooling	5 Lighting	6 Fans & Pumps	7 Water Heating	8 Other Energy			
User	User	Table C-1	Table C-1	Table C-1	Table C-1	Table C-1	Table C-1	Table C-1	Sum 3-9	2 X 10+1000

Office

--	--	--	--	--	--	--	--	--	--	--

Retail

--	--	--	--	--	--	--	--	--	--	--

Institutional

--	--	--	--	--	--	--	--	--	--	--

Total Area
(m²)

12

Total
13 Commercial and Institutional Energy Consumption (GJ/Year) =
(Sum of items in column 11)

Enter in Column 3 of Worksheet No. 7

14 Commercial Institutional Energy Consumption Indicator =
13 ÷ 12 GJ/m²/year

Enter in Column 6 of Worksheet No. 7

WORKSHEET NO.3

INDUSTRIAL ENERGY CONSUMPTION

NO.

1	2	3	4	5	6
Industrial Category	Area	Employment Density	Employment	Energy Coefficient	Total Annual Energy Consumption
	ha	Workers/ha	Workers	MJ/Worker	GJ
Table D1	User	Table D2	User or 2 x 3	Table D3	4x5 ÷ 1000

Light Industry					
Knitting					
Clothing					
Printing and Publishing					
Electric Products					
Miscellaneous					

Medium Industry					
Food and Beverage					
Plastic and Rubber					
Leather					
Textiles					
Wood					
Furniture and Fixtures					

Heavy Industry					
Paper and Allied Products					
Primary Metals					
Metal Fabricating					
Machinery					
Transport Equip					
Non Metallics and Mineral Products					
Chemicals					

7 Total Lot Area	
---------------------	--

8	Total Annual Industrial Energy Consumption = (Sum of Items in column 6) (GJ/Year)	
---	--	--

Enter in Column 3 of Worksheet No. 7

9	Industrial Energy Consumption Indicator 8 ÷ 7 (GJ/ha/year)	
---	---	--

Enter in Column 6 of Worksheet No. 7

WORKSHEET NO.4

TRANSPORTATION ENERGY CONSUMPTION

NO.

A. Trip Productions

	1	2	3	4	5
Dwelling Unit Type	No. of Units	Trips/ Unit	Annual Trips	Persons/ D.U.	Total Persons
Source	User	Tab. E1	1 X 2	Tab. E4	1 X 4

Single Family Detached					
Single Family Attached					
Low - Rise Apartment					
High Rise Apartment					

6 Total Annual Trip Productions =

7 Population =

B. Trip Attractions

8	9	10	11
Land Use Activity (Excluding Local Uses)	Floor Space (m ²) or Employees	Average Trips Per Employee or Unit Area Trips/m ² /Year	Annual Trips
Source	User	Tables E2 & E3	9 X 10

1			
2			
3			
4			
5			
6			
7			
8			

12 Total Annual Trip Attractions =

WORKSHEET NO.4 CON'T **TRANSPORTATION ENERGY CONSUMPTION**

NO.

C. Internal and Total Trips

13	Regional Population
14	Internal Person Trips
15	Total Person Trips

Source

User
$(12 \times 7) + 13$
$6 + 12 = 18$

D. Passenger - Kilometres of Travel

16	Average Trip Length (KM)
17	Total Person - Kilometres
18	Average % of Trips by Transit
19	Total Transit Passenger - KM
20	Total Automobile Person - KM

Fig. E1 and Table E5
15×16
Table E10
17×18
$17 - 19$

E. Energy Consumption

21	Energy Intensity (MJ/Pass. - KM)
22	Transit Energy Consumption (MJ/Year)
23	Average Automobile Occupancy
24	Average Auto Energy Consumption (MJ/veh. - KM)
25	Automobile Energy Consumption (MJ/Year)

Table E7
19×21
Table E8
Table E9
$20 \div 23 \times 24$

26	Total Annual Transportation Energy (GJ/Year)
----	--

$(22 + 25) \div 1000$

--

Enter in Column 3 of Worksheet No. 7

F. Energy Consumption Indicator

27	Total Residential Gross Floor Area (m ²)
28	Total Inst./Com./Industrial GFA (m ²)
29	Total Gross Floor Area (m ²)
30	Transportation Energy Consumption Indicator GJ/m ² /year

Sum of Column 2 x 3 in Worksheet No. 1
Sum of Column 9
$27 + 28$
$26 \div 29$

Enter in Column 6 of Worksheet No. 7

WORKSHEET NO.5 CONSTRUCTION ENERGY CONSUMPTION

NO.

1	2	3	4	5	6
Land Use Type	Gross Building Area m ² (User)	Energy per m ² (MJ/m ²) Table F1	Energy by Type (MJ) 2x3	Project Life Years Table F2	Annual Energy MJ/Year 4÷5

Construction of Buildings

Residential: Single Family					
Residential: Two-Four Family					
Residential: Apartment					
Commercial Office					
Commercial Retail					
Educational					
Hospitals					
Industrial					
Other					
Total Gross Building Area		Total Annual Building Construction Energy 7			

8	9	10	11	12	13
Major Service Types	Length of Service (M) (User)	Energy/m (MJ/m) Table F3	Energy by Type (MJ) 9x10	Project Life Years Table F2	Annual Energy MJ/Year 11÷12

Construction of Services

Roads					
Water					
Sanitary Sowers					
Drainage Piping					
Drainage Ditching					
Sidewalks Walkways					
Contingencies					
All Piped Services					

14 Total Annual Service Construction Energy (MJ/Year)

15 Total Annual Construction Energy Consumption (7 + 14)÷1000 GJ/Year

Enter in Column 3 of Worksheet No. 7

16 Construction Energy Consumption Indicator (15 + Total Gross Building Area) GJ/m²/year

Enter in Column 6 of Worksheet No. 7

WORKSHEET NO.6 **OPERATION OF SERVICES ENERGY CONSUMPTION**

NO.

1	2	3	4
Land Use Type	Number of Units or Area	Service Energy Factor	Annual Energy Consumption
Source	Worksheets 1, 2, and 3	Table 6B	2x3

Residential Single Family			
Residential Two-Four Family			
Residential Apartment			
Commercial - Office			
Commercial - Retail			
Educational			
Hospital			
Industrial - Light			
Industrial - Heavy			
Other			

5 Sub Total (Sum of Column 4)	
---	--

6 Energy Consumption Contingency Factor (See Section 3.6.2)	
---	--

7 Total Annual Energy Consumption for Operation of Services (Sum) + 3000 kJ/Year	
---	--

Enter in Column 3 of Worksheet No. 7

8 Operation of Services Energy Indicator (7 + Sum of Column 2 Worksheet No. 5) kJ/m²/year	
---	--

Enter in Column 6 of Worksheet No. 7

WORKSHEET NO.7 ENERGY CONSUMPTION - SUMMARY

NO.

1		2	3	4	5	6
Line No.	Category	Workload Source	Total Annual Energy Consumption GJ/year	Distribution & (Total of 100)	Workload Source (Indicators)	Energy Consumption Indicators

7	Residential	No. 1 Line 10			No. 1 Line 12	GJ/Unit/year
8	Commercial and Institutional	No. 2 Line 13			No. 2 Line 14	GJ/m ² /year
9	Industrial	No. 3 Line 8			No. 3 Line 9	GJ/ha/year
10	Transportation	No. 4 Line 26			No. 4 Line 30	GJ/m ² /year
11	Construction	No. 5 Line 15			No. 5 Line 16	GJ/m ² /year
12	Operation of Services	No. 6 Line 7			No. 6 Line 8	GJ/m ² /year

13	Total Annual Energy Consumption of Proposed Development (Sum of Column 3)	GJ/year
----	---	---------

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